STAFF REPORT

IMPACTS ON CONSUMERS:
WELFARE ECONOMICS IN THE MULTIPRODUCT CASE

ESCS Staff Report NRED 80-2

Marie Leigh Forbush, NRED/ESCS
Russell Gum, NRED/ESCS
William E. Martin, Dept. of Ag. Econ./U. of Ariz.
Dennis Cory, Dept. of Ag. Econ./U. of Ariz.
Reuben N. Weisz, NRED/ESCS
Lloyd Teigen, NED/ESCS

NRE

Economics, Statistics, and Cooperatives Service

United States Department of Agriculture

IMPACTS ON CONSUMERS: WELFARE ECONOMICS IN THE MULTIPRODUCT CASE

ESCS Staff Report NRED 80-2

Marie Leigh Forbush, NRED/ESCS
Russell Gum, NRED/ESCS
William E. Martin, Dept. of Ag. Econ./U. of Ariz.
Dennis Cory, Dept. of Ag. Econ./U. of Ariz.
Reuben N. Weisz, NRED/ESCS
Lloyd Teigen, NED/ESCS

Natural Resource Economics Division
Economics, Statistics and Cooperatives Service
U.S. Department of Agriculture
Washington, D.C. 20250

Jan. 1980

IMPACTS ON CONSUMERS: WELFARE ECONOMICS IN THE MULTIPRODUCT CASE. By Marie Leigh Forbush, Russell Gum, William E. Martin, Dennis Cory, Reuben N. Weisz, Lloyd Teigen, Natural Resource Economics Division; Economics, Statistics, and Cooperatives Service; U.S. Department of Agriculture; Washingtion, D.C. 20250; (January) 1980.

ABSTRACT

Measurement of net benefits experienced by consumers is a fundamental component in any comprehensive policy impact analysis. Various methods are employed by economists to gauge impacts on consumers. The objective of this research is to test empirically alternate approaches to measurement of consumer welfare. The validity, accuracy and usefulness of each measure is examined. The empirical test evaluates the economic impacts of the reduction in corn yields.

Key words: consumer surplus, welfare economics, econometric models, pest control economics.

AUTHORS

Forbush, Gum, and Weisz are Agricultural Economists in NRED, ESCS, USDA. Teigen is an Agricultural Economist in NED, ESCS, USDA. Martin and Cory are on the Faculty in the Department of Agricultural Economics, University of Arizona.

CONTENTS

SUMMARY AND CONCLUSIONS

All agricultural policy effects both producers and consumers. However, agricultural economists have traditionally spent most of their effort in policy research analyzing the producer impacts. In addition, most, if not all, previous empirical studies on consumer impacts have not been done in a manner consistent with welfare economic principles.

This report analyzes in a theoretically correct manner the impact on consumers of a regulation against use of pesticides in corn production. Projections of a three percent decrease in yields were accepted as reasonable and are the basis for the analysis of consumer impacts. Consumer impacts were defined in terms of the amount of income which would have to be given consumers to make them exactly as well off as they would be with pesticides allowed for corn production. These consumer impacts were considered for the complete livestock sector, beef, pork, poultry, and dairy products. The cross-commodity model was utilized to project differences in quantities and retail prices of goods in the livestock sector.

Consumer impacts using the correct method were found to be 49 billion dollars over the period 1980 to 1985. This is equivalent to .4 percent of disposable income for the same period, or 218 dollars per capita for the period.

Other methods of calculating consumer impacts were investigated. Two easily calculated indices, the Paasche index and the Laspeyres index bound the true impact and were calculated to be 215 and 222 dollars per capita respectively. The average of these indices, in addition to being extremely easy to calculate, is, for all practical purposes, the same as the "true" answer. Two methods which have been frequently used but which are theoretically incorrect, the change in expenditure method, and the difference in areas under the demand and above price which is often incorrectly assumed to be a measure of consumer surplus, were also used to estimate impacts. Both of these methods gave gross underestimates of the consumer impacts, 139 dollars per capita for the expenditures method and 72 dollars per capita for the erroneous consumer surplus method.

Policy analysts can easily predict consumer impacts in a theoretically appropriate manner using the principles described in this paper and developed originally by Hicks in the 1940's. There is no excuse for not using the correct measures.

INTRODUCTION

Governmental agencies have, as part of their mandate, the responsibility for analyzing the effect of impending or potential policies on consumers. The USDA, as part of its policy role, is accountable specifically for the investigation of impact on consumers due to agricultural policy. The problem is that in many cases empirical studies conducted in this regard are incomplete and perhaps misleading. The two examples that follow typify the kind of analysis conducted by the USDA. These reports, and others like them, constitute part of the information decision makers utilize in policy evaluation.

In "Nitrite in Bacon" (USDA 1978d), the policy in question is a ban on the use of nitrite in curing bacon. In order to assess this policy's effect on the agricultural sector, a computer model was employed. This econometric model provided a simplified description of the agricultural sector, with existing institutional arrangements presupposed.

A set of baseline estimates for economic indicators were projected. The projections served as a "without policy" case, a reference point for future impacts. Once this foundation was set, the ban on nitrite was supposed. The econometric model traced the impact on

projections over a 5 year period. In "Nitrite in Bacon", economic projections consist of prices, production and incomes.

Results were summarized and presented in terms of their deviation from baseline estimates. Unfortunately, this is where the inquiry ended. It stopped short of a final goal; what is presented is a compilation of fragments. Deviations in price, production and incomes may be important components in a comprehensive assessment of costs and benefits. But these statistics, without further interpretation, are meaningless in terms of their welfare implications for consumers.

The reader is left to sort out numbers and interpret them as he sees fit. The problem is that many decision makers do not have the background necessary to translate raw economic data into a recommendation for or against a policy. In fact in "Nitrite in Bacon" there is not enough information for any person, regardless of profession, on which to base a logical decision.

"The Income Redistribution Effects of the Meat Import Act" (Teigen 1977) takes a different approach to policy analysis. As in the bacon study, a set of computer programs were used to determine baseline and impact solutions for a set of economic indicators. However, the import study goes beyond simple tabulation of results. The study goes on to evaluate income transfers as changes in total expenditures on beef with and without the act. It must be noted, however, that the transfers are not directly correlated with changes in welfare.

Figure 1 is the study's graphical representation of the market for beef. The study claims the Import Act resulted in a decrease in the

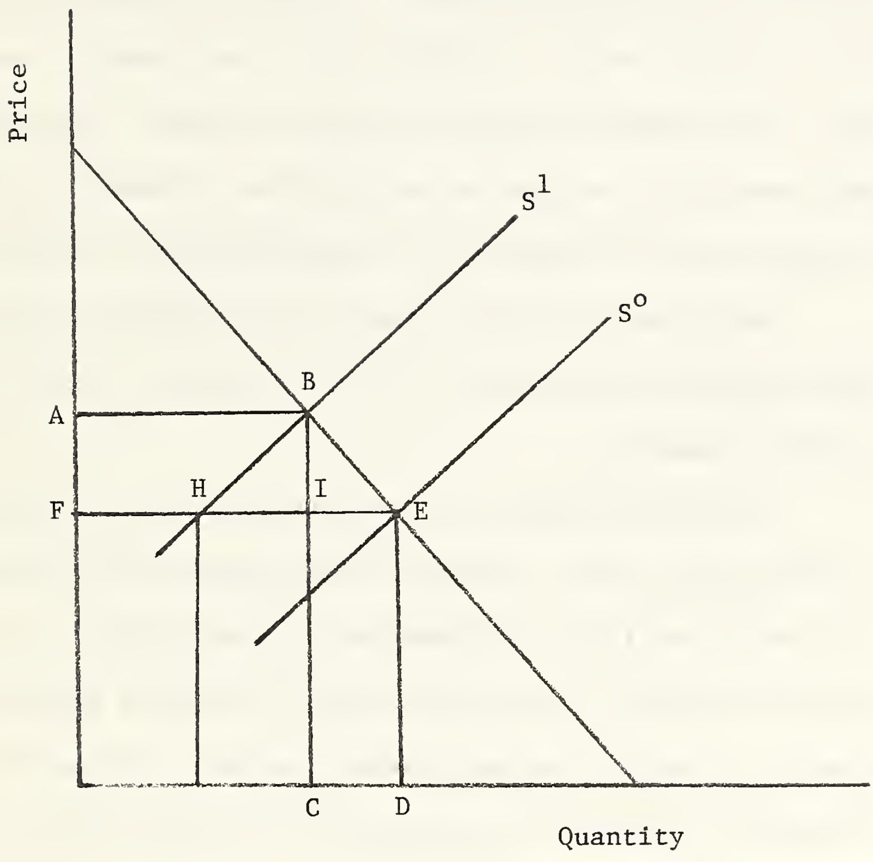


Figure 1. Impacts of the beef Import Act. --Taken from Teigen 1977.

supply of beef from S^o to S^1. The report states "the change in expenditures represent the net position of consumers" (Teigen 1977, p. 4). CDEI is explained as a transfer from foreign producers to consumers, ABHF as a transfer from consumers to producers and BHI as a transfer from consumers to input suppliers. It is apparent that these areas have little to do with area ABEF, the loss in consumer welfare as dictated by welfare theory. Consequently, losses born by consumers as a result of the import act have been underestimated. The Import Act study exemplified the type of analysis that interprets economic data, but stops short of estimating an ultimate impact on consumers.

The objective of this study is to demonstrate empirically, in a conceptually correct manner, the way effects of a policy on consumers may be measured.

The policy chosen to be evaluated is a ban on insecticides in the production of corn. Pimental and Shoemaker (1974) assert that such a ban would result in a 3% reduction in corn yields. It is assumed that this decrease in supply will impact livestock production and reverberate throughout the agricultural sector. The resulting sequence of economic conditions is recorded over a 6 year period until the impacts appear to stabilize.

The Cross-Commodity Forecasting System (C.C.F.S.) is the econometric tool chosen to evaluate the effect of a policy on economic indicators. It is an aggregate (national) agricultural paradigm designed to provide consistent forecasts on individual commodities (Boutwell et al. 1976). Given forecasts on economic variables

derived from the C.C.F.S., alternate measures of the change in consumer welfare are estimated. These measures are analyzed in terms of their differences and the resulting implications for consumer welfare theory.

THEORETICAL CONSTRUCTS

Historical Review

The concept of surplus value entered economic theory in 1844. Dupuit claimed a consumer may receive surplus value from consuming a particular good or service. In 1844 Dupuit stated that surplus value exists if there is a positive "difference between the sacrifice which the purchaser would be willing to make in order to get it and the purchase price he has to pay in exchange" (see Jules Dupuit, "On the Measurement of the Utility of Public Works," International Economic Papers, Vol. 2, 1952, pp. 83-110, reprinted in Kenneth J. Arrow and Tibor Scitovsky (eds.), Readings in Welfare Economics, Richard D. Irwin, Inc., 1967). He suggested that since total willingness to pay by a consumer is the sum of marginal valuations as expressed by demand, and the total price paid is the market price times the number of units purchased, surplus value is represented by the area below the demand curve and above the price line. Dupuit was satisfied with the adequacy of this monetary measure of a consumer's "wishes".

In 1898 Marshall popularized Dupuit's measure. However, Marshall addressed utility directly (Currie et al. 1971). Therefore, his interpretation of surplus value seems to be the utility experienced from having a certain quantity of a good minus the utility lost through having to pay for it.

Dupuit's and Marshall's measures are equivalent provided that:

1. The marginal utility of income is constant (This assumption does not necessarily imply an underlying utilitarian philosophy. It simply states that successive increments of income add constant increments to utility);
2. All implications are drawn ceteris paribus. That is, this analysis applies only to movements along a particular demand curve, with nominal income and tastes and preferences held constant.

Given these two assumptions, a change in consumer welfare may be evaluated as follows (Figure 2). Initially the consumer is at point A, consuming Q_o at price P_o. His consumer surplus is $OBAQ_o - OP_oAQ_o = P_oBA$. If the supply of this good increases from S^o to S^1, the consumer will buy Q_1 at price P_1. At this point, his surplus is $OBCQ_1 - OP_1CQ_1 = P_1BC$. Thus, consumer's surplus has increased by area P_oACP_1.

When several goods are considered, total consumer's surplus (or change in total consumer's surplus) is simply the sum of individual results.

Marshall's analysis was extended from a consumer's surplus to consumers' surplus. Just as an individual's marginal valuations are reflected by his personal demand, a group of consumers' collective valuations are reflected by market demand. Thus, the same sort of analysis can be applied to groups. Of course in this analysis a change in group welfare indicates nothing of the distribution of change.

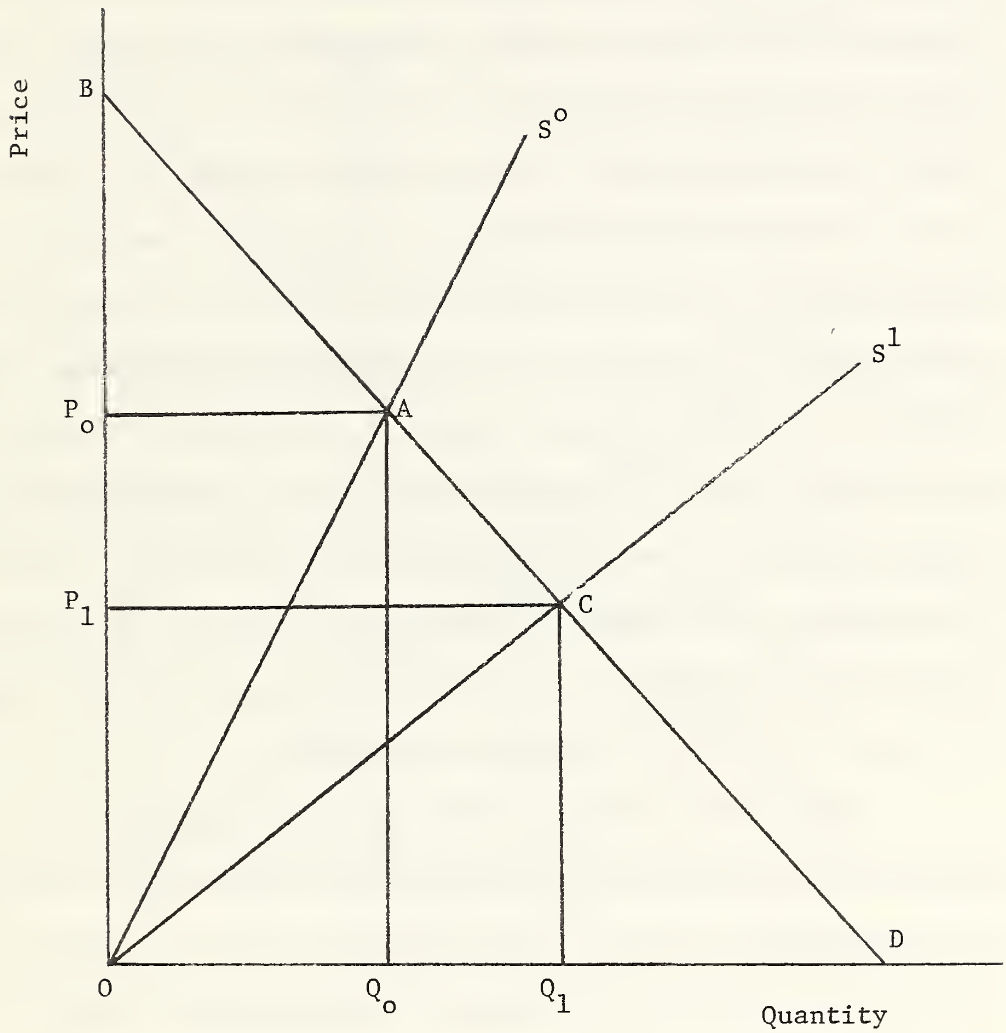


Figure 2. Change in Marshallian surplus.

After Marshall, the concept of consumer's surplus was largely ignored until revitalized by Hicks in 1939. Hicks claimed the usefulness of the concept of surplus is in its ability to make possible an evaluation of a potential Pareto-improvement (Hicks 1939). An optimum situation is one where no further improvements can be made. This situation occurs when the marginal social benefits of an item or activity equals the marginal social cost to provide or enjoy it. Consider Figure 3. If demand reflects marginal social benefits and supply reflects marginal social cost, the optimum locus is at point A, where supply equals demand. At point A, the sum of producer and consumer surplus is maximized. Consumer surplus if P_oBA. If restriction on supply is hypothesized, say to S^1, determination of the change in consumers' surplus allows us to evaluate deviation from optimality. When supply is restricted, the consumer must pay P_1 and buys Q_1. His surplus has decreased by area P_oACP_1. The concept of consumers' surplus plays a vital role in the field of welfare economics.

Hicks (1941) recognized that Marshall's assumption of constant marginal utility of money could limit this concept's serviceability. Constant marginal utility of income implies that the consumer's demand schedule for a particular commodity is unaffected by changes in income due to a price change. This situation may hold approximately if:

1. a small proportion of total income is spent on the commodity,
2. the net change in income is small, or
3. income elasticity of demand for this good is very small.

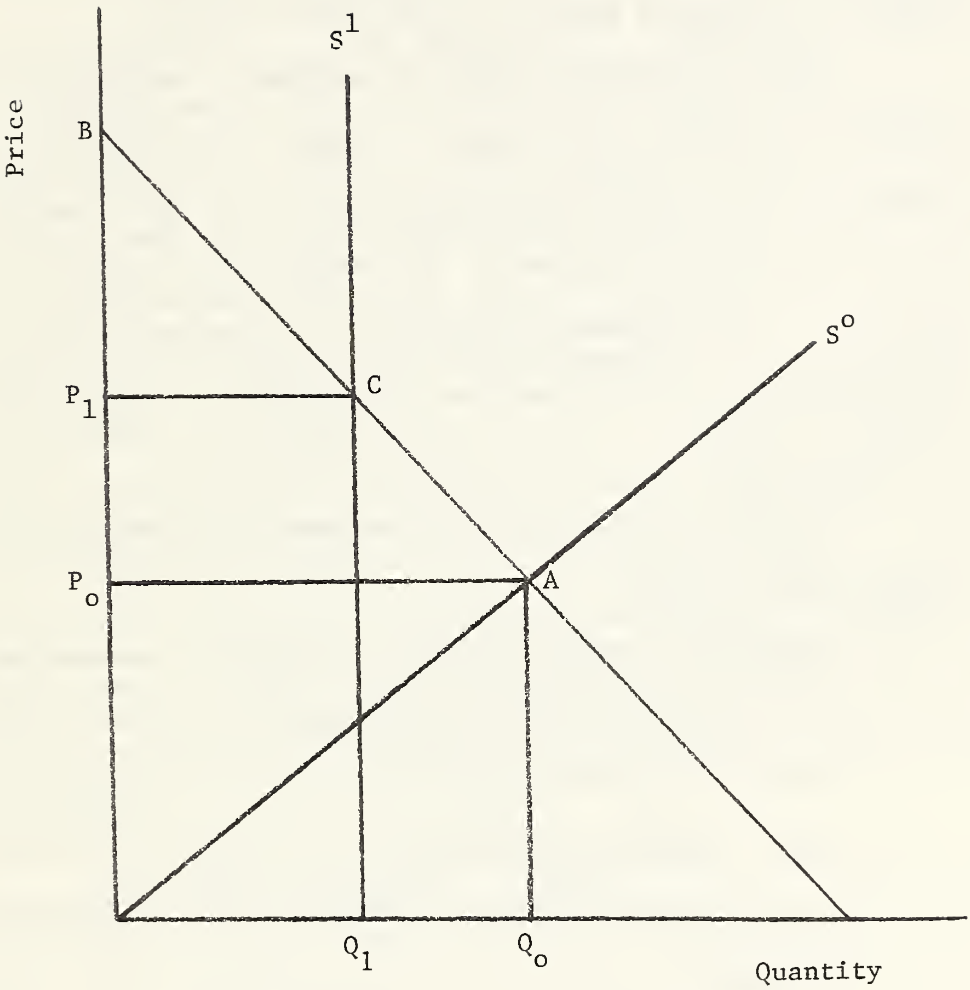


Figure 3. Marshallian surplus and deviation from the social optimum.

Hicks felt these two cases might cover the majority of instances. However, in cases where 1 and 2 do not hold (and consequently in cases with relatively large welfare implications) Marshallian surplus is an ambiguous measure of true surplus value.

Hicks refined measurement of consumer's surplus in order to allow for the effects of changes in income. This refined measurement was termed compensating variation which is "in terms of money income, the gain which accrues to the consumer as a result of a fall in price . . . the compensating variation in income whose loss would just offset the fall in price and leave the consumer no better off" (Hicks 1939, pp. 38-41).

Henderson (1941) found two fundamental discrepancies in Hicks' compensating variation:

a. Marshallian surplus measures the amount a consumer would pay if he could not get the good otherwise, for the opportunity to buy at the existing price, the amount <u>which he is in fact buying</u>. Compensating variation is the amount the consumer would pay to buy the good at the existing price, <u>in whatever quantity he wishes</u>.

b. Compensating variation will differ depending on whether the consumer is giving up income in order to obtain the good or gaining income in order to abandon purchase of the good. Recently Martin, Tinney and Gum (1978) and Randall (1978) have described this distinction as dependent on property rights.

Which measure is appropriate depends on whether the consumer has a right to his initial or subsequent welfare level.

In reference to problem a. consider Figure 4. The consumer begins with income Y_o. Given preferences I_o and price P_o, the consumer is in equilibrium at point A. If the price of good X drops to P_1, the consumer would be at point B. If the consumer is constrained to his subsequent quantity (as with Marshallian surplus) the amount of income he could forego and remain on I_o may be visualized as Y_oY_1. Given the opportunity to buy any quantity after compensation (as with compensating variation) the consumer would be at C. In this situation, the consumer could forego Y_oY_2 and remain at his original level of utility. Y_oY_1 and Y_oY_2 will coincide only when the slope of I_o at D is equal to the slope of I_1 at B; that is, where the marginal rate of substitution between income and good X is unchanged by the increase in real income. In other words, this is the case where the marginal utility of income is constant.

In reference to problem b. review Figure 5. Again the consumer starts with income Y_o, tastes I_o and I_1 with prices P_o and P_1 respectively. But in this case he is not paying for the privilege of buying at the lower price, he is accepting money in order to give up the lower price. In other words, he has a right to the second (higher) welfare position I_1, rather than the initial position as in the previous case. If the consumer is constrained to buying the original bundle, the minimum he would accept is Y_oY_1 (AC) (equivalent surplus). If he is

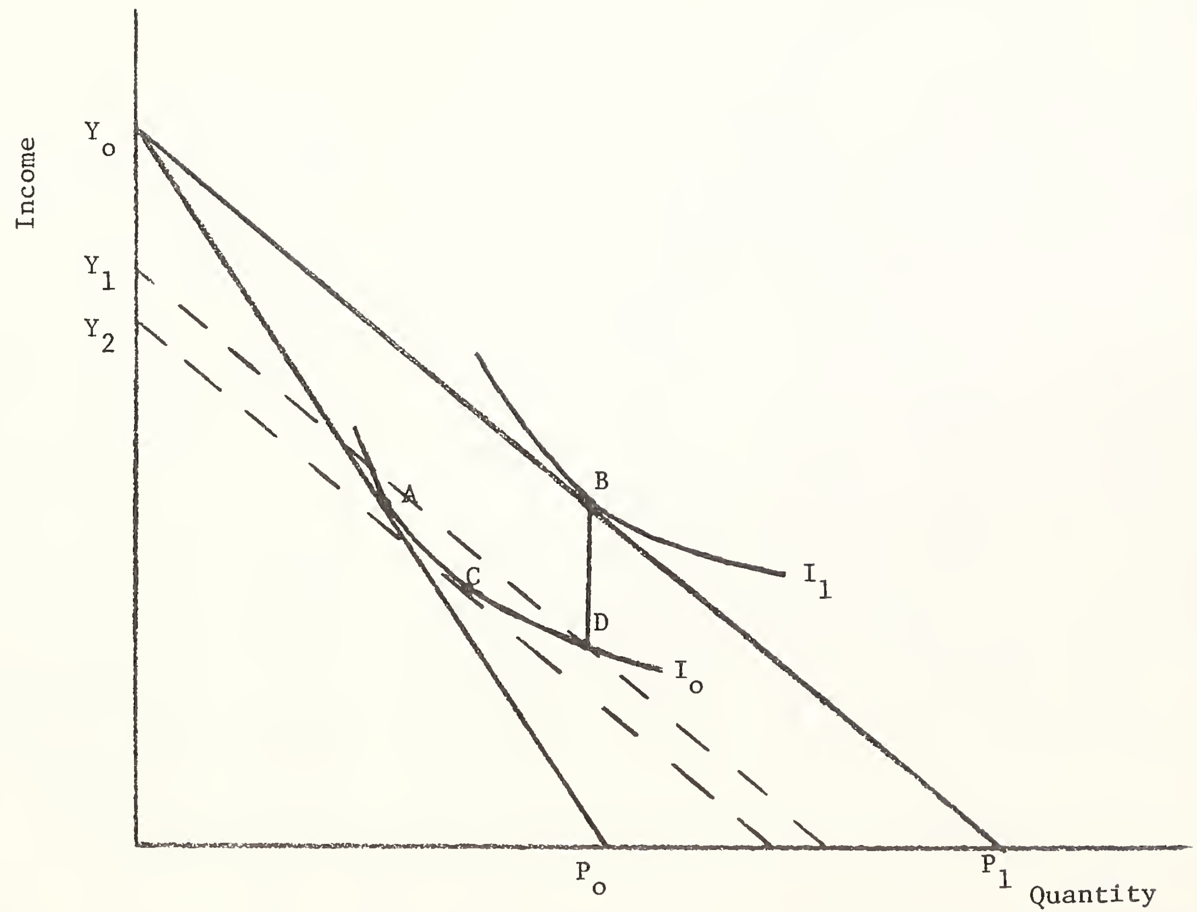


Figure 4. Measures of consumer welfare with the quantity purchased constrained and unconstrained.

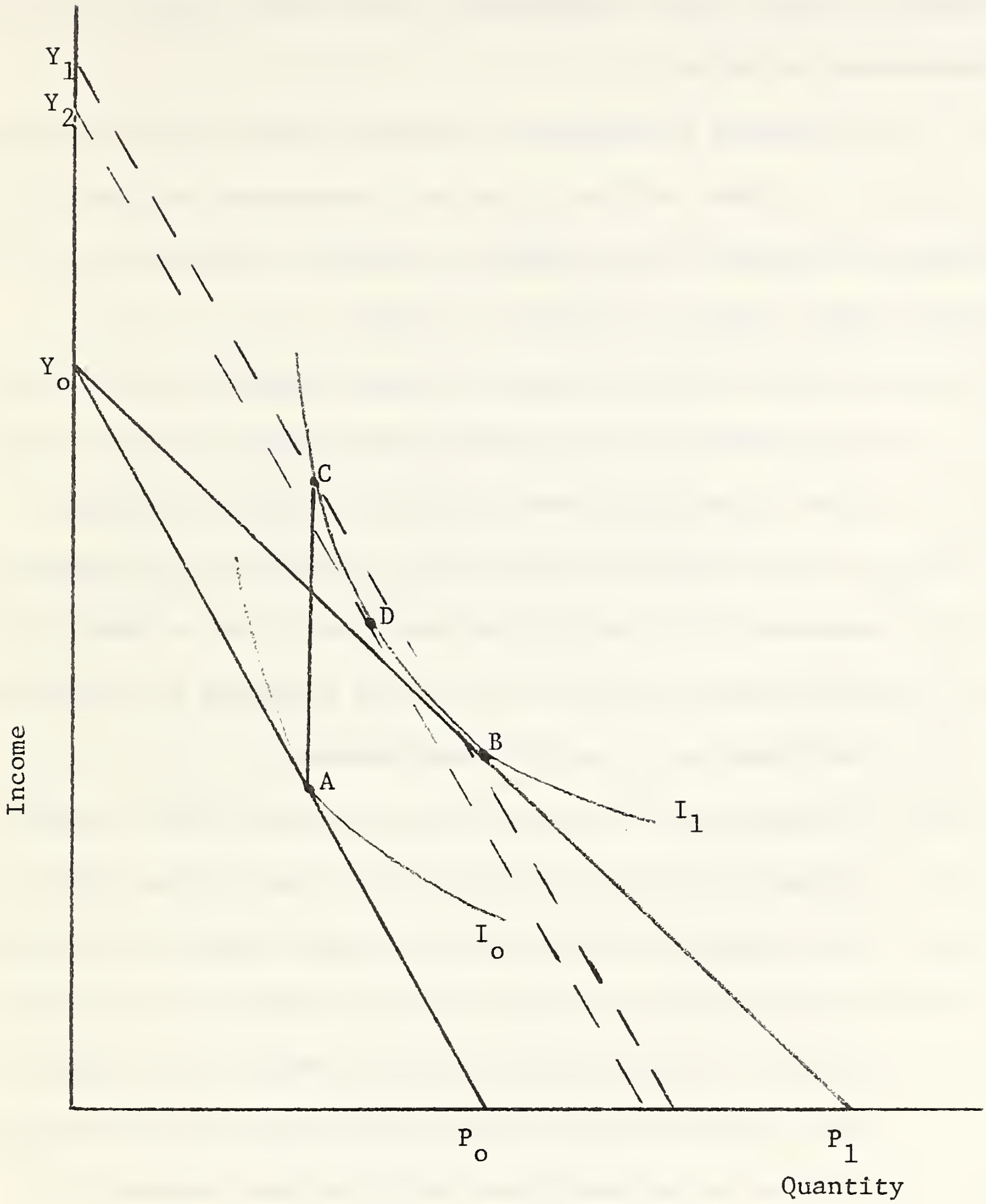


Figure 5. Measures of consumer welfare based on compensation required to forego purchase of a good.

allowed to adjust after compensating, the required amount is Y_oY_2 (AD) (equivalent variation).

In response to Henderson's critique, Hicks (1942) defined four measures of consumer surplus. They are compensating variation (CV), compensating surplus (CS), equivalent variation (EV), and equivalent surplus (ES). They are defined as follows:

1. CV = the amount of money, paid or received, that will leave the consumer at his initial welfare level, after a change in price, if he is allowed to make optimizing adjustment.
2. CS = the amount of money paid or received, that leaves the consumer at his initial welfare level, after a change in price, if he is constrained to buy at the new price the quantity he would have bought without compensation.
3. EV = the amount of money paid or received, that leaves the consumer at the subsequent welfare level, in the absence of a price change, if he is allowed to make optimizing adjustments.
4. ES = the amount of money paid or received, that leaves the consumer at the subsequent welfare level, in the absence of a price change, if he is constrained to buy at the initial price the quantity he would have bought without compensation.

Hicks (1942) and Henderson (1941) stated that which measure is proper depends on the context in which it is used. Mishan (1947-48) has argued that in all plausible circumstances only compensating and equivalent variation should be considered. Patinkin (1963) supports this view given that perfectly competitive situations are under

consideration. Given these arguments, and the fact that with agricultural products, consumers are not usually constrained to consume a particular quantity of a good, the remainder of this research focuses only on the measures of variation.

Figure 6 illustrates the general relationship between EV, Marshallian surplus (MS) and CV for both a price increase and decrease in terms of consumer demand functions. Conversion of indifference maps and budget constraints to reflect the consumer's demand for a commodity is done in two steps. First, on the upper graph utility is maximized subject to the original budget constraint (Y_o) given an initial relative price for X of P_o, in order to determine the quantity purchased (X_o). Second, on the lower graph, the intersection between price line P_o and quantity X_o is plotted (0). The process is repeated after the price change. After the price change, the consumer maximizes utility subject to Y_o, which results in consumption of X_1 (upper graph). The intersection of P_1 and X_1 is plotted on the lower graph (1). Segment P_o01P_1 on the lower graph is the area to the left of demand and between prices. This area is the change in Marshallian surplus and the income equivalent of a change in welfare, if income effects are zero.

The magnitude of CV and EV in relation to MS can be determined by graphing in terms of demand, what quantity of a good would be purchased under the conditions defined by compensating and equivalent variation. These quantities are determined on indifference maps and transposed onto the graph describing demand. The quantities consumed under conditions required by CV and EV are X_c and X_e, respectively. By

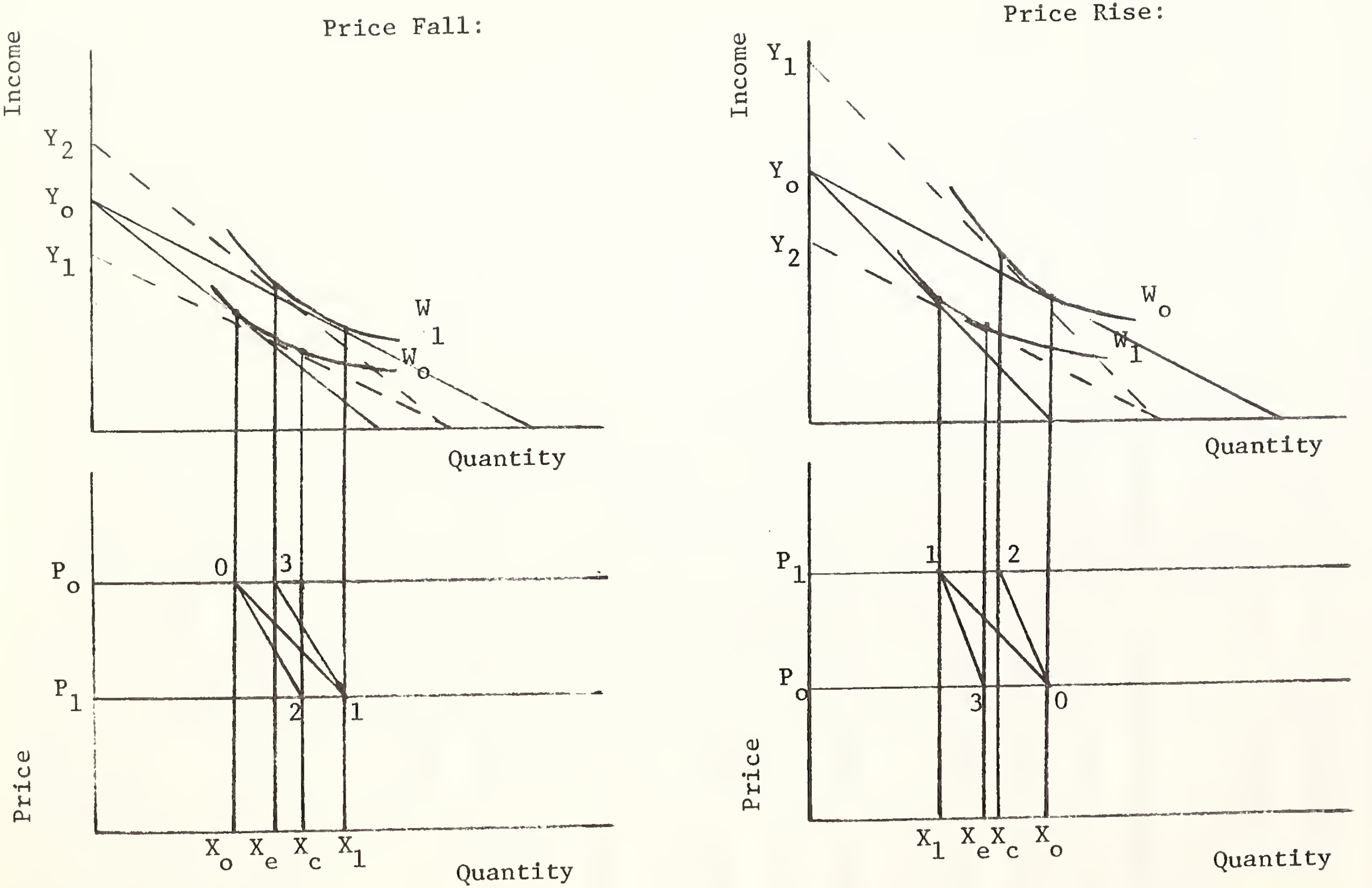


Figure 6. Change in Marshallian surplus, compensating variation and equivalent variation for a price increase and decrease.

matching up information from indifference maps and budget constraints with areas under demand, compensating variation is seen to be equal to Y_oY_1 which is equal to P_o02P_1. Equivalent variation (Y_oY_2) is equal to area P_o31P_1.

The transposing procedure allows one to verify that for a price decrease equivalent variation > Marshallian surplus > compensating variation. For a price increase equivalent variation < Marshallian surplus < compensating variation.

"In Consumers' Surplus and Index Numbers", Hicks (1942) introduces two index numbers in addition to CV and EV. The Laspeyres and Paasche indices place limits on the values CV and EV can assume.

The Laspeyres index is defined as the exact amount of money paid or received by the consumer that is necessary to buy the original amount of the good at the new price, without remainder. The Paasche index is defined as the change in income which would enable the second set of goods to be purchased at the original price without remainder.

The Laspeyres index number always places a bound on compensating variation. Consider the case of a price increase. Suppose a man originally purchases 10 units of a good at $5 per unit. His total expenditures amount to $50. If the price increases to $7 per unit he would have to spend $70 to buy 10 units. It is obvious that the <u>maximum</u> he could be compensated <u>without raising his utility above his welfare</u> level is $20.

Similarly, the Paasche index always plans a bound on equivalent variation. Continuing with the above example, suppose the consumer actually purchased 8 units after the price increase. The consumer

is spending \$56 on 8 units. If the price was still \$5, he would only have to spend \$40 on 8 units. Sixteen dollars (\$56 - \$40) represents the <u>maximum</u> amount the consumer could pay in order to buy at the lower, original price and remain at his subsequent welfare level.

Both Laspeyres and Paasche indices are illustrated for a price decrease, graphically and mathematically in Figure 7. The change in Marshallian surplus (P_oADP_1) is less than Paasche but greater than Laspeyres. In addition, compensating variation must be less than Marshallian and greater than the Laspeyres index, whereas equivalent variation will be greater than the change in Marshallian and less than the Paasche index. In total, for a price decrease (given demand is fixed), the following relationship must hold:

Laspeyres Index < Compensating Variation < Change in Marshallian Surplus < Equivalent Variation < Paasch Index.

The reverse is true for a price increase, i.e.:

Laspeyres Index > Compensating Variation > Change in Marshallian Surplus > Equivalent Variation > Paasche Index.

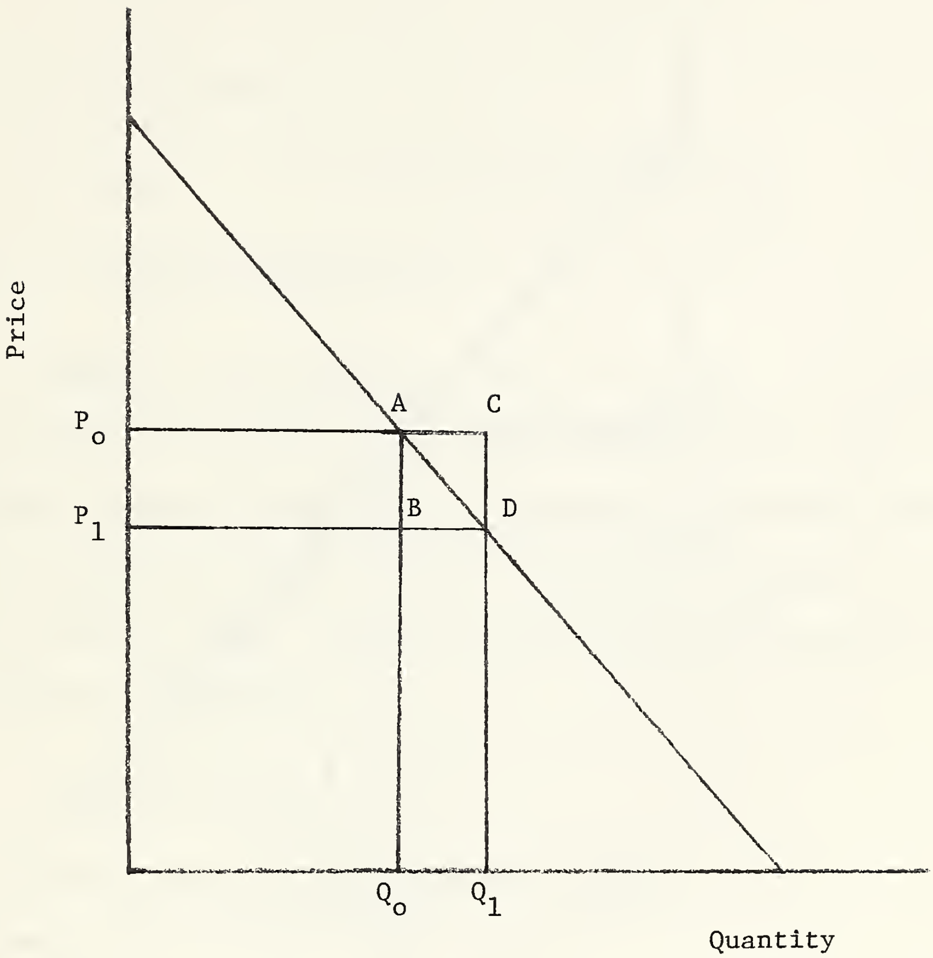
The latter relationship is illustrated in Figure 8. The negative sign indicates a decrease in welfare.

The Paasche and Laspeyres indices are simple to calculate. A more rigorous examination of CV and EV is necessary to determine mathematical estimates. Hicks (1942) conducts his inquiry as follows.

Assume the consumer spends all his income (Y) on goods $X_1 \ . \ . \ . \ X_N$ at prices $P_1 \ . \ . \ . \ P_N$

His utility (U) may be described as:

$$U = U(X_1 \ . \ . \ . \ X_N) \tag{1}$$



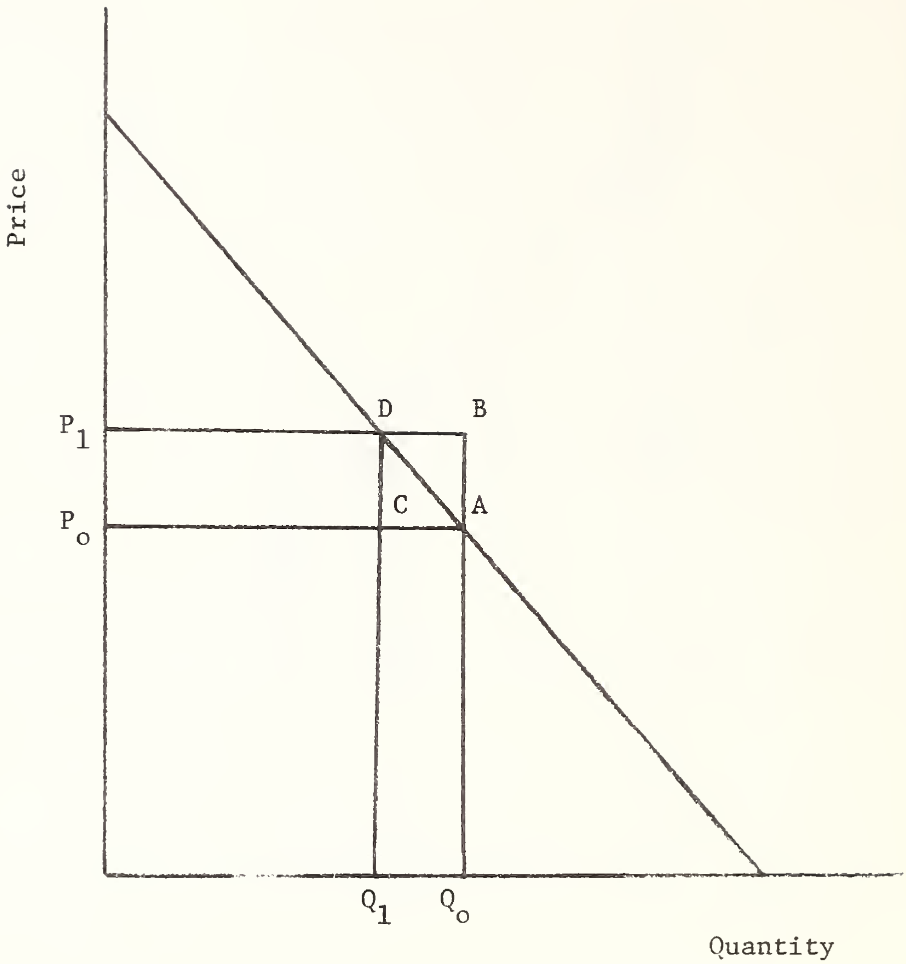
P_o = original price $\qquad$ Q_o = original quantity

P_1 = subsequent price $\qquad$ Q_1 = subsequent quantity

Paasche Index = $(P_o - P_1)(Q_1) = P_oCDP_1$

Laspeyres Index = $(P_o - P_1)(Q_o) = P_oABP_1$

Figure 7. Laspeyres and Paasche indices for a price decrease.



P_o = original price

P_1 = subsequent price

Q_o = original quantity

Q_1 = subsequent quantity

Paasche Index = $(P_o - P_1)(Q_1) = -P_oCDP_1$

Laspeyres Index = $(P_o - P_1)(Q_o) = -P_oABP_1$

Figure 8. Laspeyres and Paasche indices for a price increase.

where:

$$Y = \sum_{R=1}^{N} P_R X_R \quad . \tag{2}$$

Therefore in equilibrium:

$$U_R = \lambda P_R \tag{3}$$

where: λ = marginal utility of Y.

Redefine U as a function of $P_1 \ldots P_N$ and Y. If we assume prices change from P_R to $P_R + \Delta P_R$ with Y unchanged, the consumer experiences a change in utility $(\Delta_1 U)$. Equivalent variation is the change in income $(Y + \Delta_E Y)$ with prices unchanged, that leads to the same change in utility $(\Delta_2 U)$. In order to define equivalent variation we must solve the equation:

$$\Delta_1 U = \Delta_2 U \text{ for } \Delta_E Y \quad . \tag{4}$$

Hicks uses a quadratic approximation to obtain:

$$\Delta_2 U = \frac{dU}{dY} \Delta_E Y + 1/2 \frac{d^2 U}{dY^2} (\Delta_E Y)^2 \quad . \tag{5}$$

If (2) is differentiated partially with respect to Y we obtain:

$$\sum_{R=1}^{N} P_R \frac{dX_R}{dY} = 1 \quad . \tag{6}$$

Therefore:

$$\frac{dU}{dY} = \sum_{R = 1}^{N} U_R \frac{dX_R}{dY} = \lambda \sum_{R = 1}^{N} P_R \frac{dX_R}{dY} = \lambda(1) = \lambda . \quad (7)$$

Consequently:

$$\Delta_2 U = \lambda \Delta_E Y + 1/2 \frac{d\lambda}{dY} (\Delta_E Y)^2 . \quad (8)$$

If the marginal utility of income is assumed constant (as does Marshall):

$$\frac{d\lambda}{dY} = 0 \quad (9)$$

so:

$$\Delta_E Y = \frac{\Delta_2 U}{\lambda} . \quad (10)$$

A nearer approximation is found by solving the quadratic (8) with terms of higher orders than the second being neglected:

$$\Delta_E Y = \frac{\Delta_2 U}{\lambda} - 1/2 \frac{1}{\lambda} \frac{d\lambda}{dY} {\frac{\Delta_2 U}{\lambda}}^{2} . \quad (11)$$

Expanding $\Delta_1 U$ similarly:

$$\Delta_1 U = \sum_{R=1}^{N} \frac{dU}{dP_R} \Delta P_R + 1/2 \sum_{R=1}^{N} \sum_{S=1}^{N} \frac{d^2 U}{dP_R dP_S} \Delta P_R \Delta P_S . \quad (12)$$

If (2) is differentiated partially with respect to P_R and set equal to 0, we arrive at:

$$\sum_{S=1}^{N} P_S \frac{dX_S}{dP_R} = -X_R \ . \tag{13}$$

Therefore:

$$\frac{dU}{dP_R} = \sum_{S=1}^{N} U_S \frac{dX_S}{dP_R} = \lambda \sum_{S=1}^{N} P_S \frac{dX_S}{dP_R} = -\lambda X_R \tag{14}$$

and

$$\frac{d^2U}{dP_R dP_S} = \frac{d}{dP_S} (-\lambda X_R) = -\lambda \frac{dX_R}{dP_S} - X_R \frac{d\lambda}{dP_S} \ . \tag{15}$$

Therefore:

$$\Delta_1 U = -\lambda \sum_{R=1}^{N} X_R \Delta P_R - 1/2\lambda \sum_{R=1}^{N} \sum_{S=1}^{N} \frac{dX_R}{dP_S} \Delta P_R \Delta P_S -$$

$$1/2 \sum_{R=1}^{N} X_R \Delta P_R \sum_{S=1}^{N} \frac{d\lambda}{dP_S} \Delta P_S \ . \tag{16}$$

To obtain equivalent variation we set $\Delta_1 U = \Delta_2 U$ and substitute from (16) into (11), neglecting terms of higher orders than the second.

$$\Delta_E Y = \sum_{R=1}^{N} X_R \Delta P_R - 1/2 \sum_{R=1}^{N} \sum_{S=1}^{N} \frac{dX_R}{dP_S} \Delta P_R \Delta P_S -$$

$$1/2 \sum_{R=1}^{N} X_R \Delta P_R \sum_{S=1}^{N} \frac{1}{\lambda} \frac{d\lambda}{dP_S} \Delta P_S -$$

$$1/2 \frac{1}{\lambda} \frac{d\lambda}{dY} \left(\sum_{R=1}^{N} X_R \Delta P_R \right)^2 \ . \tag{17}$$

Since:

$$\frac{d^2U}{dP_R dY} = \frac{d^2U}{dY dP_R} \tag{18}$$

then,

$$\frac{d}{dP_R}\lambda = \frac{d}{dY}(-\lambda X_R) \tag{19}$$

and

$$\frac{1}{\lambda}\left(\frac{d\lambda}{dP_R} + X_R\frac{d\lambda}{dY}\right) = -\frac{dX_R}{dY} \tag{20}$$

therefore:

$$\Delta_E Y = -\sum_{R=1}^{N} X_R\,\Delta P_R - 1/2\sum_{R=1}^{N}\sum_{S=1}^{N}\frac{dX_R}{dP_S}\,\Delta P_R\,\Delta P_S +$$

$$1/2\sum_{R=1}^{N} X_R\,\Delta P_R\sum_{R=1}^{N}\frac{dX_R}{dY}\,\Delta P_R\ . \tag{21}$$

Using a similar procedure Hicks defines compensating variation as:

$$\Delta_C Y = -\sum_{R=1}^{N} X_R\,\Delta P_R - 1/2\sum_{R=1}^{N}\sum_{S=1}^{N}\frac{dX_R}{dP_S}\,\Delta P_R\,\Delta P_S -$$

$$1/2\sum_{R=1}^{N} X_R\,\Delta P_R\sum_{R=1}^{N}\frac{dX_R}{dY}\,\Delta P_R\ . \tag{22}$$

If the marginal utility of income is constant so that $\frac{dX}{dY} = 0$, both formulas reduce to:

$$- \sum_{R=1}^{N} X_R \Delta P_R - 1/2 \sum_{R=1}^{N} \sum_{S=1}^{N} \frac{dX_R}{dP_S} \Delta P_R \Delta P_S \tag{23}$$

which is equivalent to a change in Marshallian surplus.

We can verify the convergence of CV, EV and MS when $\frac{dX}{dY} = 0$ through example. If the price of only one commodity changes and the marginal utility of income is constant, CV = EV = MS and equation 23 becomes:

$$-X \Delta P - 1/2\ dX/dP \quad (\Delta P)^2 \tag{23}$$

where:

X - original quantity

and:

dX/dP = inverse of slope of demand.

In reference to Figure 9 for the one commodity example, CV = EV = MS

$$= -2\ (1) - 1/2\ (2)\ (1 \cdot 1) = -3 \cdot \tag{23}$$

If two commodites are considered (good i and good j) and $dX/dY = 0$, equation 23 becomes:

$$(-X_i \Delta P_i - 1/2 \quad \frac{dX_i}{dP_i} \Delta P_i + \frac{dX_i}{dP_j} \Delta P_j \quad \Delta P_i) +$$

$$(-X_j \Delta P_j - 1/2 \frac{dX_j}{dP_j} \Delta P_j + \frac{dX_j}{dP_i} \Delta P_i \quad \Delta P_j) \tag{23}$$

In reference to Figure 10, the preceeding formula may be visualized as:

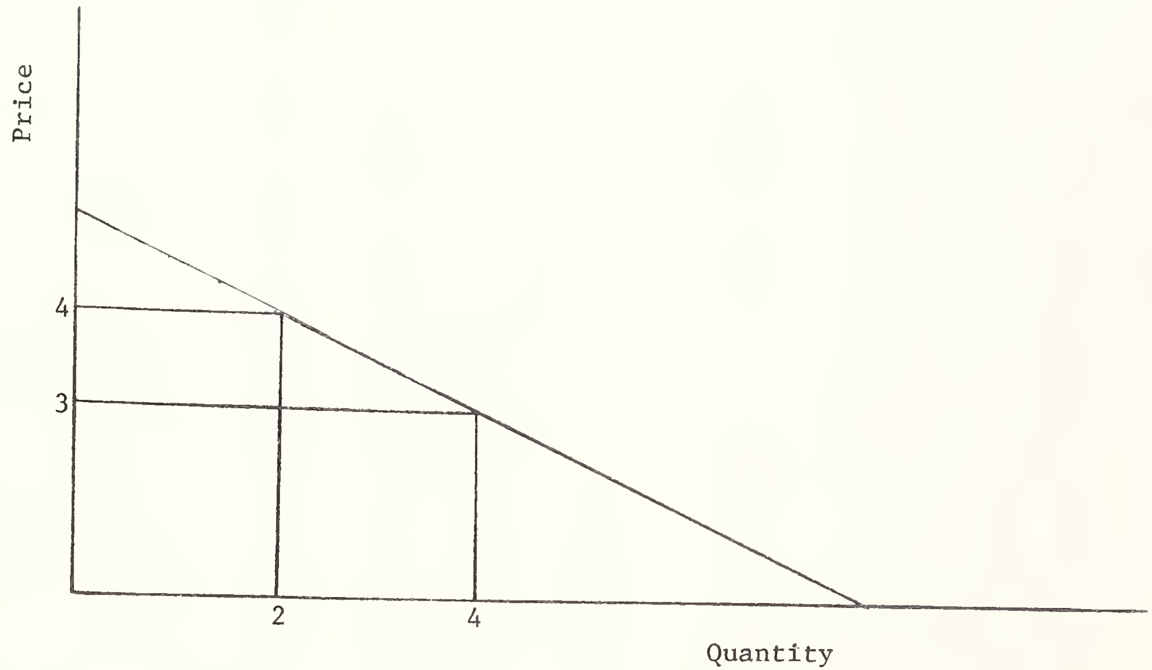


Figure 9. Measurement of Marshallian surplus, compensating variation and equivalent variation when marginal utility of income is constant and one price changes.

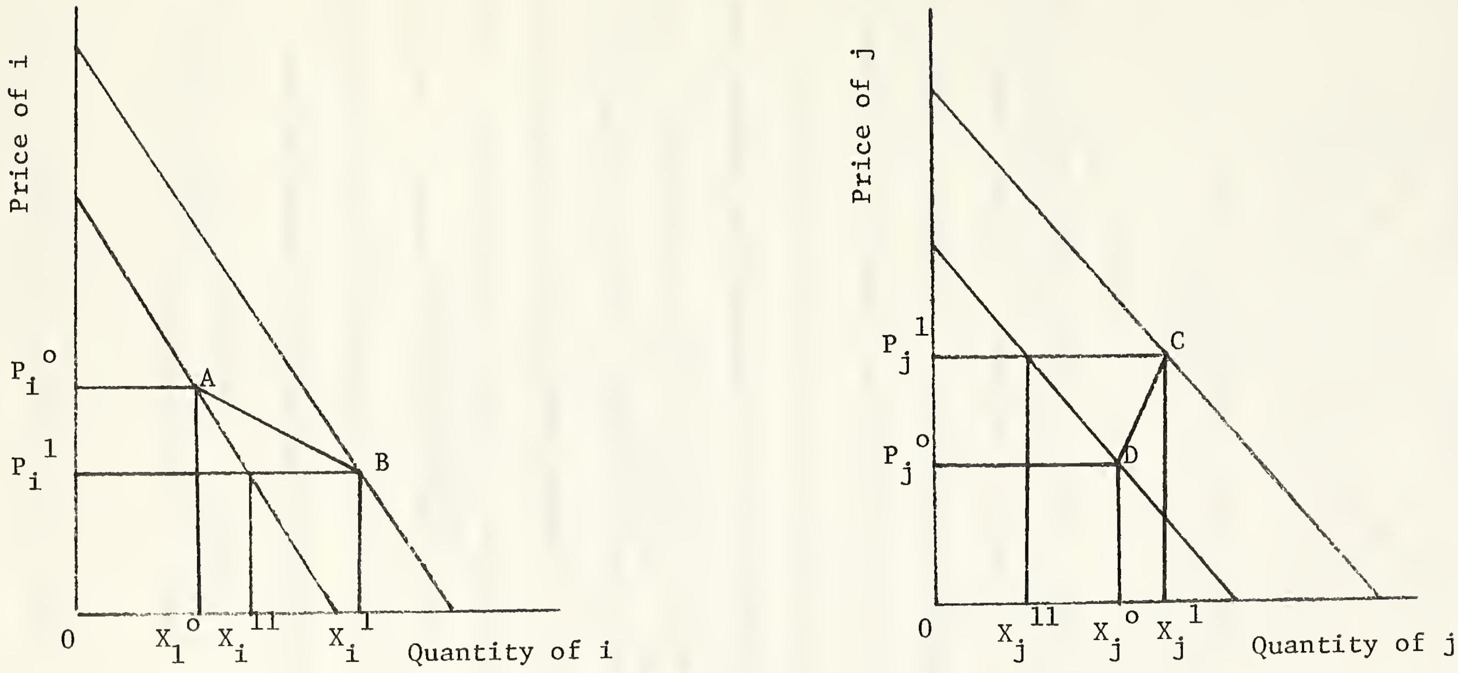


Figure 10. Two commodity examples of a change in Marshallian surplus.

$$- (OX_i^{\,o}) \quad (-) \ (P_i^{\,o} P_i^{\,1}) \ - 1/2 \ \ X_i^{\,o} X_i^{\,11} + X_i^{\,11} \ X_i^{\,1}$$

$$(-) \ P_i^{\,o} P_i^{\,1} \ + (-) \ (X_j^{\,o}) \ (\ (+) \ P_j^{\,o} P_j^{\,1}) \ - 1/2$$

$$-X_j^{\,o} X_j^{\,11} + X_j^{\,11} \ X_i^{\,1} \quad (+) \ P_j^{\,o} \ P_j^{\,1} \ =$$

$$+ P_i^{\,o} \ AB \ P_i^{\,1} - P_j^{\,1} \ CD \ P_j^{\,o} \ . \tag{23}$$

Equations 21 and 22 do not require ceteris paribus conditions. Demand may be allowed to fluctuate. In fact, constant nominal income is not a necessary restriction. A change in nominal income "has the same effect as if all prices had changes in corresponding proportions" (Hicks 1942, p. 135).

Furthermore, these concepts may be applied to a group of consumers. One may aggregate before calculation by using market demand to reflect prices and quantities. Or one may aggregate after calculation, by using individual demand curves and summing individual results.

If the marginal utility of income varies, compensating and equivalent variation deviate from the change in Marshallian surplus. In effect the third term in equations 21 and 22 for equivalent and compensating variation, respectively, become active.

$$EV = - \sum_{R=1}^{N} X_R \Delta P_R - 1/2 \sum_{R=1}^{N} \sum_{S=1}^{N} dX_R/dP_S \ \Delta P_R \ \Delta P_S \ +$$

$$1/2 \sum_{R=1}^{N} X_R \ \Delta P_R \ (\sum_{R=1}^{N} dX_R/dY \ \Delta P_R) \tag{21}$$

$$CV = -\sum_{R=1}^{N} X_R \Delta P_R - 1/2 \sum_{R=1}^{N}\sum_{S=1}^{N} dX_R/dP_S \, \Delta P_R \, \Delta P_S -$$

$$1/2 \sum_{R=1}^{N} X_R \Delta P_R \left(\sum_{R=1}^{N} dX_R/dY \, \Delta P_R \right) \qquad (22)$$

The term $1/2 \sum_{R=1}^{N} X_R \Delta P_R \left(\sum_{R=1}^{N} \frac{dX_R}{dY} \Delta P_R \right)$ in both equations represents an income effect. $\sum_{R=1}^{N} X_R \Delta P_R$ may be interpreted as the amount of income freed or tied up due to price changes. $\sum_{R=1}^{N} dX_R/dY \Delta P_R$ represents the change in purchase of X due to the difference in money freed or tied up.

If one desires to break up the entire term so the adjustment may be made commodity by commodity the result for commodity i follows: Income effect $(\alpha_i) = 1/2 \sum_{R=a}^{n} X_R \Delta P_R \, (dX_i/dY \Delta P_i)$. Use of the income effect term allows more precise estimation of a change in welfare.[1]

Recent Developments

Path Dependency

Burns (1973) addresses the problem of path dependency in determining the income equivalent of a change in utility. It has been shown that both compensating and equivalent variation are income

---

[1] For a critical discussion of Hicks' derivation, see Pfouts (1953, pp. 324-326).

equivalents for the same change in utility. Which measure is appropriate depends on whether the consumer has a right to the initial or subsequent position. As a result, their magnitude differs. Burns states that "the key to the discrepancy is that any evaluation of the income equivalent of a given utility change will depend upon the value of the marginal utility of income along the path on which the evaulation takes place" (Burns 1973, p. 339).

Given:

Utility (U) = marginal utility of income (λ) times an income equivalent (Y) and

$$\lambda_1 Y_1 = U = \lambda_2 Y_2$$

if: $\lambda_1 > \lambda_2$

then: $Y_1 < Y_2$.

Consider Figure 11. If consumer welfare increases from W_o to W_1 due to a decrease in price from P_o to P_1, one may measure the income equivalent of his change in utility as Y_oY_1 (compensating variation) or Y_oY_2 (equivalent variation).

Compensating variation assumes the consumer moves along W_0 from A to C then from C to B as a result of income changes alone. Equivalent variation assumes the consumer moves from A to D due to income changes, then along W_1 from D to B. Given this is a normal good the marginal value of income will be greater at C than it is at D (since income at C is lower). Since both measures estimate the same change in utility, the income equivalent for equivalent variation will

Figure 11. Relative marginal utility of income along alternate price adjustment paths.

be larger than that for compensating variation, since the path ACB implies a lower marginal utility of income. (Utility = marginal utility of income · income equivalent).

Compensating and equivalent variation evaluate the income equivalent of the welfare change along a rather indirect adjustment path. One would expect an intermediate, more direct route between A and B. However, there is an infinite number of paths (and corresponding income equivalents) that could be taken. Fortunately realistic income equivalents will lie between the limiting expressions of CV and EV.

Estimation of CV and EV are considered adequate, since any error due to path dependency would most likely be overwhelmed by error in regression analysis used to provide the demand data.

Income Effects

Much of the controversy surroundings the Hicksian measures of welfare lies in the importance and magnitude of income effects. As the size of income effects increase, the more divergent CV, EV and MS become. As this variance amplifies, more significance must be attached to choosing one measure over another.

Hause (1975, p. 1152) states that there is "little purpose in assuming spurious precision in estimation for distinguishing between alternatives measures." Hause cites 3 items that may justify exclusion of income effects in empirical work:

1. "The standard errors of the regression parameters of econometric demand functions (from which preference structures are

inferred) are almost always large enough to swamp differences attributable to income effect."

2. The quantitative errors incorporated by assuming a consistent social preference structure probably overwhelm income effects.
3. In most general equilibrium contexts, the relevant income effect will be much smaller than that for a short term demand function.

Willig (1976) concurs with Hause. He shows mathematically that when a consumer faces a ceteris paribus price change, it is possible to determine compensating and equivalent variation if one has information about the change in Marshallian surplus, the consumers base income and his income elasticity of demand. While he presents exact formulas, his approximation formulae are:

$$CV \quad \frac{A + nA^2}{2m} \qquad\qquad EV \quad \frac{A - nA^2}{2m}$$

where:

m = base income

n = income elasticity of demand

A = change in Marshallian surplus with a change in price.

Willig derives precise upper and lower bounds on percentage errors for approximating CV and EV. He determined that if the consumer's income elasticity is between $\pm$ 1 and the change in Marshallian surplus with a change in price is less than 5% of total income, CV and EV will be within 2% of the Marshallian measure.

He believes that these two conditions include the majority of instances. Based on the above, Willig states these "results imply that change in Marshallian surplus is usually a very good approximation to the appropriate (CV and EV) welfare measures" (Willig 1976, p. 589). Willig implies that income effects do not warrant a complete reformation of the techniques economists use to measure consumer welfare.

Gordon and Knetsch (1979) dispute the belief that CV and EV should be of similar magnitude. And they are doubtful that income effects account for the entire difference between CV and EV. Their dissent is based on empirical evidence.

CV can be described as maximum willingness to pay to continue an activity. EV is the minimum amount the consumer must be compensated in order to forego the same activity. Knetch and Gordon cite four surveys that question consumers' willingness to pay for and required compensation to give up a particular activity. The results of these surveys yield EV's of from 2.8 to 20 times the magnitude of CV.

The authors attempt to determine the factors influencing this discrepancy through multiple regression. The regressions indicated that income has a positive relationship both to CV and EV. However, the best regressions developed explained 61% of the variation in CV and only 12% of the variation in EV. Gordon and Knetsch conclude that "the regressions are a weak test of sorts, but they provide no support for the income effect being the complete explanation of the difference in response . . . the results seem to offer contradictory evidence" (Gordon and Knetsch 1979, p. 5).

Doubt as to the explanatory power of the income effect is augmented by using survey results to infer preference structures. A British Columbia angler survey was used to generate the following data (Figure 12):

mean income = \$12,000 = Yo

price of fishing = 0

median willingness to pay = \$35

median required compensation = \$700.

Since the price of this activity is zero, a horizontal price line is appropriate. The consumer begins at point A, with Y_o = \$12,000. Given the opportunity to fish, the consumer moves to C, increasing his welfare from I_o to I_1. The median willingness to pay suggests I_o runs through B and Y_o. The median compensation required implies I_1 runs through C and Y_2. If these curves are to be believed, there is a very large income effect.

If this process is repeated with a base income of \$12,500, I_1 and I_2 intersect, violating the very assumption that allows indifference maps to be a practical, logical tool for economists.

Gordon and Knetsch conclude that based on empirical evidence, the size and explanatory power of an income effect is highly suspect. They recommend better testing procedures in order to gain better insight into welfare measures and their differences.

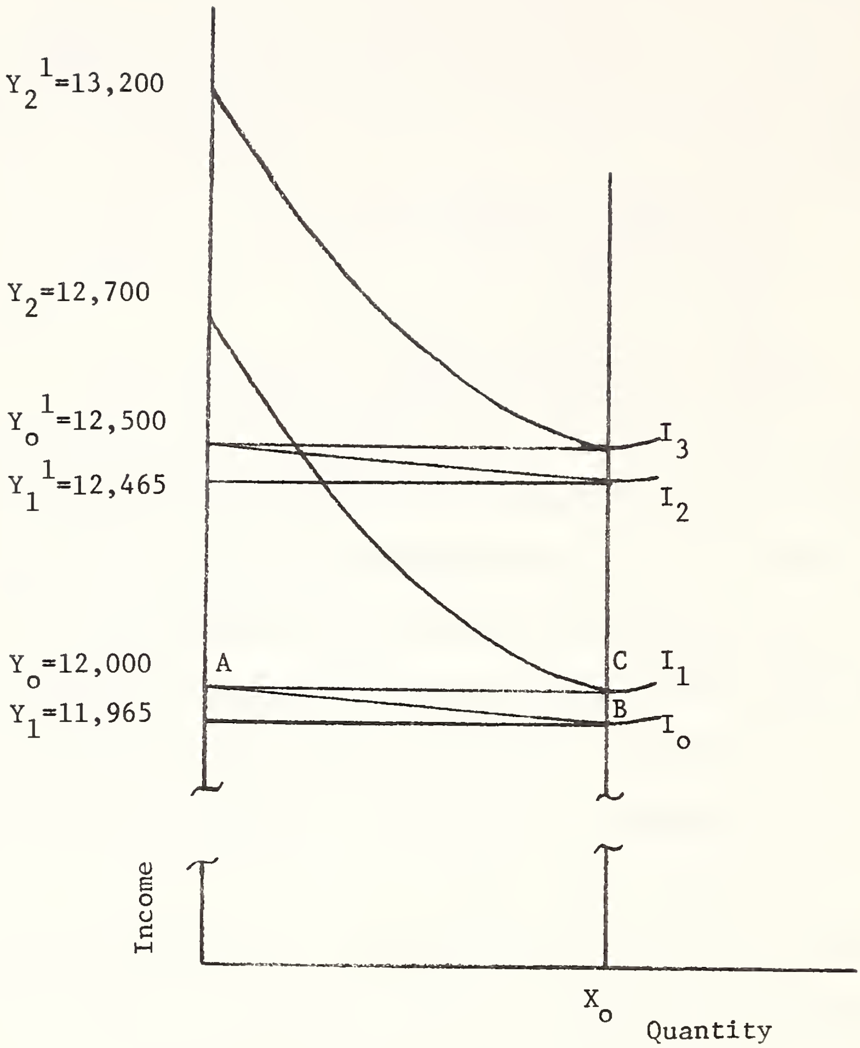


Figure 12. Preference structures inferred from empirical studies. --Taken from Gordon and Knetsch 1979, p. 7.

Noncomparability

Hause (1975) pointed out an important theoretical deficiency in the practical use of compensating variation. Although CV can determine the superiority of one consumption pattern over another, it may fail to order the relative desirability of three or more consumer bundles. Consider Figure 13.

In case 1, the consumer begins at point A with income Y_o. If the price of X decreases from P_o to P_1, he may move to point B, with his utility increasing from I_o to I_1. In this case CV is Y_oY_1 with point B superior to A.

An alternate course of events may be the following. In case 2 the consumer begins at point A. If the price of good X drops to P_2 and his income simultaneously drops to Y_2, he will move to point F. Again, his utility has increased from I_o to I_1. In this instance $CV = Y_2Y_3$, with F superior to A.

In both cases, the consumer experienced an identical change in utility. However, Y_oY_1 will equal Y_2Y_3 only when there is no income effect. If an income effect does exist, the two CV's will not be equal. As a result either point B or point F will arbitrarily be ranked as superior to the other, with no basis in reality.

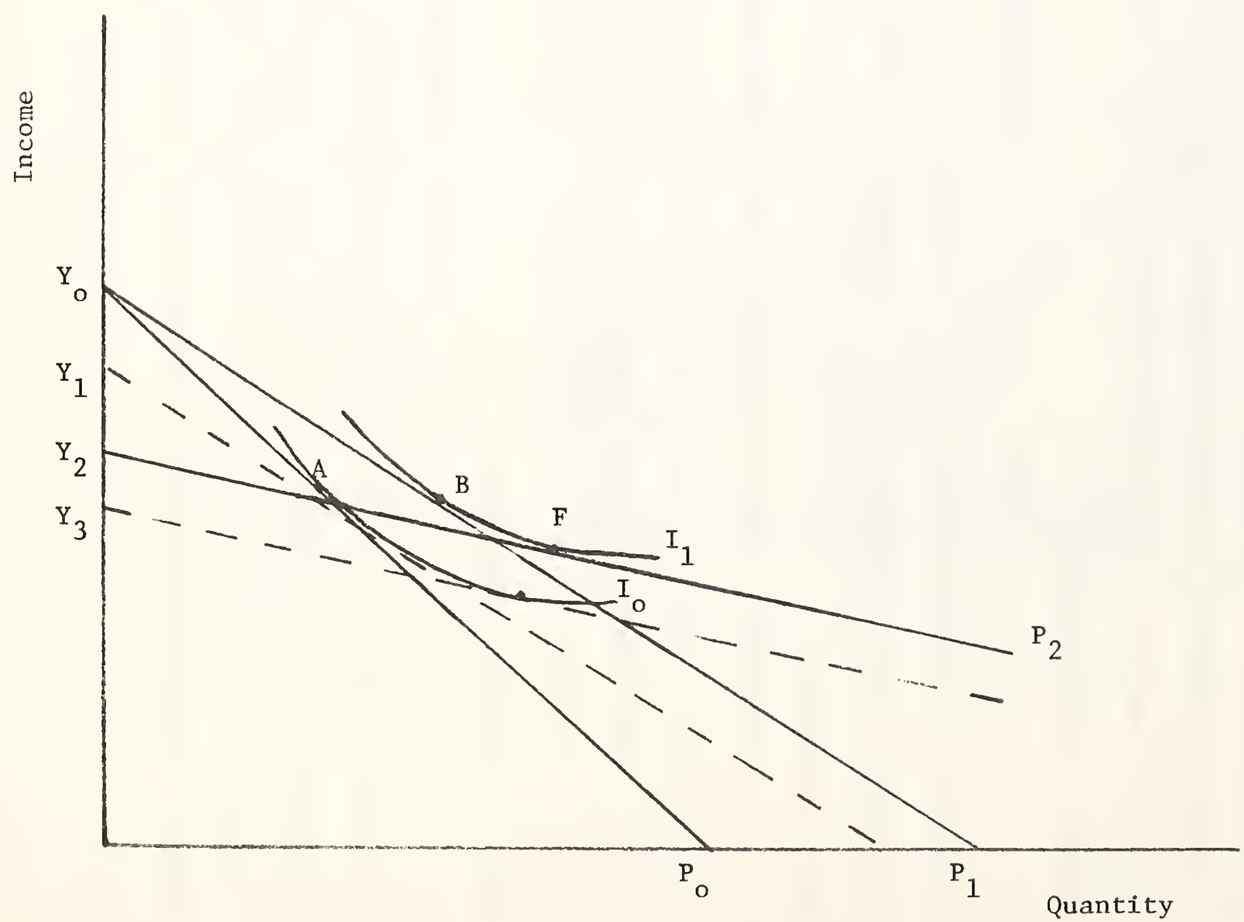


Figure 13. The noncomparability problem.

DESCRIPTION OF THE ECONOMETRIC MODEL

The objective of this research is to demonstrate alternative measures of consumer welfare, within the context of a ban on insecticides in the production of corn. The study considers the nation's consumers as a whole. However, the study has been restricted to put within reach a logical assessment of welfare dynamics.

Total expenditures by consumers have been categorized by the Bureau of Labor Statistics into food, housing, apparel, transportation, health and recreation represented by the consumer price index (USDA, 1978c). Of these, concentration is on the food group. Specifically, our focus is on consumption of 11 livestock products, which consist of pork, beef, veal, chicken, turkey, eggs, ice cream, evaporated milk, fluid milk, cheese and butter. These products make up approximately 50% of all food consumed at home or about 10% of total expenditures (Table 1).

In order to assess the impact of a ban on insecticides on consumer welfare as a function of livestock product consumption, information on a variety of economic indicators is necessary. Because of the difficulty in sorting out all the interrelationships within the agricultural sector, a comprehensive forecasting system is needed. This tool must translate commodity interrelationships into an accurate set

Table 1. Relative importance of items in the consumer price index, December 1976 -- Adapted from USDA 1978c, p. 68.

Components	Percentage of all Items	Percentage of Major Groups
All items	100.000	---
Food	23.667	---
Food-at-home	18.456	100.000
Meats	4.504	24.404
Fish	.636	3.446
Poultry	.560	3.034
Eggs	.588	3.186
Dairy products	2.841	15.393
Fats and oils	.578	3.132
Fresh fruits	.755	4.091
Fresh vegetables	1.008	5.462
Processed fruits and vegetables	1.255	6.800
Cereals	.844	4.573
Bakery products	1.693	9.173
Sugar and sweets	.705	3.820
Nonalcoholic beverages	1.418	7.683
Prepared and partially prepared foods	1.071	5.803
Food away-from-home	5.210	100.000
Housing	34.202	100.000
Shelter	21.256	62.148
Fuel and utilities	5.414	15.830
Household furnishings and operation	7.532	22.022
Apparel and upkeep	9.194	100.000
Mens and boys	2.467	26.833
Womens and girls	3.378	36.741
Footwear	1.383	15.042
Other apparel	1.966	21.384
Transportation	13.548	100.000
Private	12.227	90.250
Public	1.321	9.750
Health and recreation	19.013	100.000
Medical care	6.734	35.418
Personal care	2.554	13.433
Reading and recreation	5.143	27.050
Other goods and services	4.582	24.099
Miscellaneous	.376	---

Table 1. Continued

Components	Percentage of all Items	Percentage of Major Groups
Special groups		
Commodities	62.468	100.000
Services	37.532	100.000

of quantitative forecasts for economic indicators on each commodity. The Cross Commodity Forecasting System is the econometric model chosen to provide these economic indicators.

The C.C.F.S. is a system of models that include the eleven commodities of direct interest plus feed grains, soybeans and wheat (Figure 14). The system "reflects, in an annual aggregate sense, the underlying direct and cross economic effects of the crop and livestock sector" (Teigen and Womack 1979, p. 1). The individual commodity models are linked via common variables (Figure 15). The entire system includes 158 endogenous and 136 exogenous variables. This linked system is the product of years of research by seasoned commodity specialists in USDA.

Each commodity model contains the following equations to be estimated:

a. retail demand

b. farm demand

c. investment demand

d. supply of live animals

e. supply of carcasses

f. product stocks

g. conversion relationships

h. inventory accounting

i. supply and demand identities.

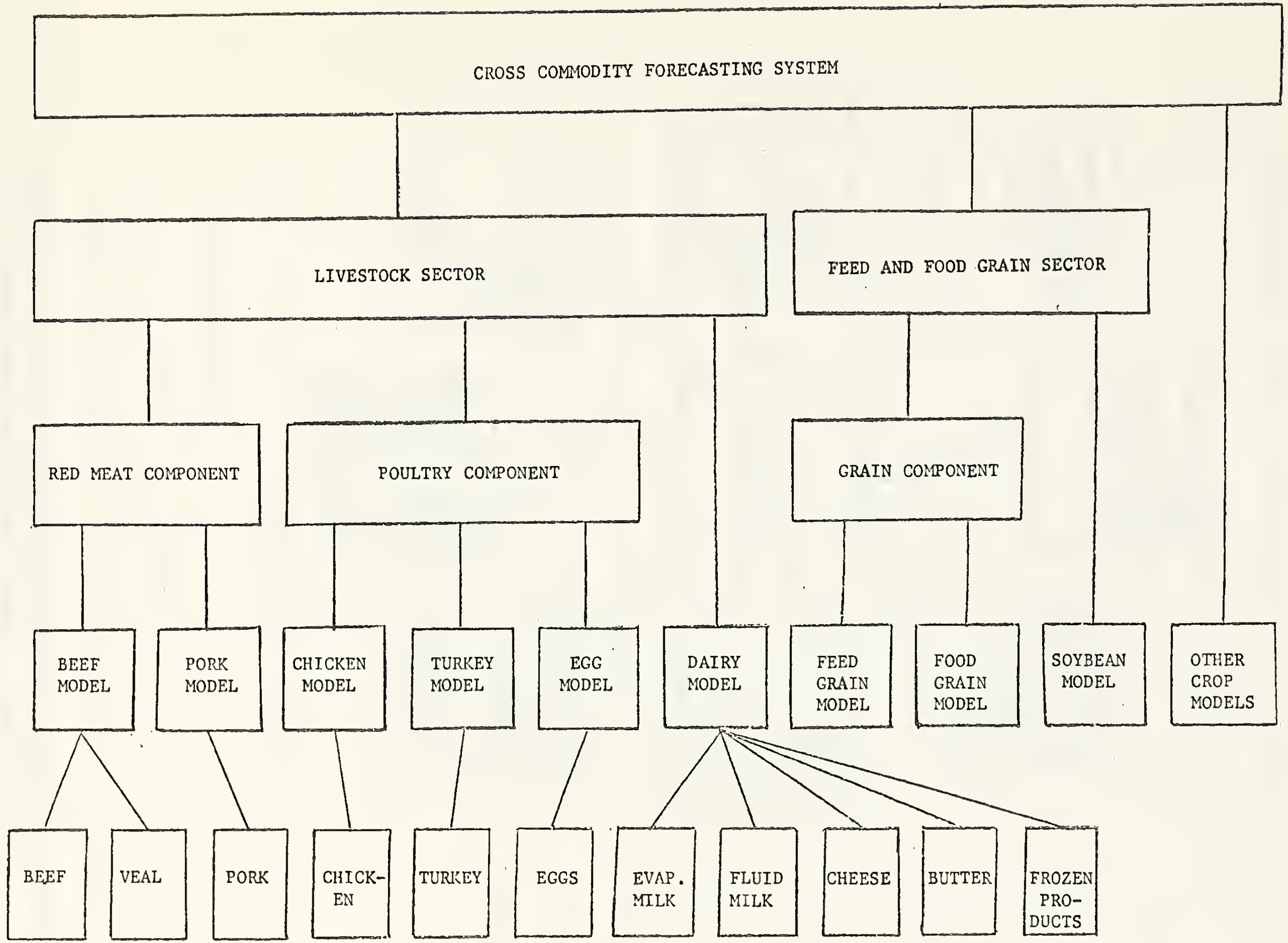


Figure 14. Structural characteristics of the Cross Commodity Forecasting System.
--Adapted from Boutwell et al. 1976, p. 45.

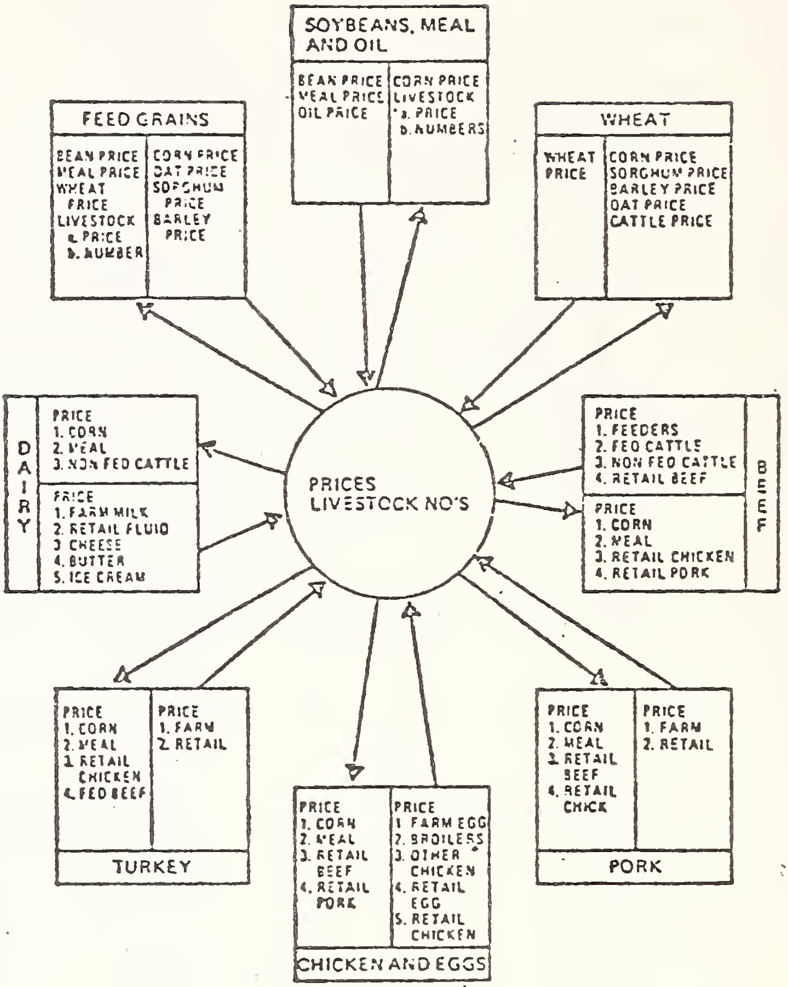


Figure 15. Price linkage mechanisms of the Cross Commodity Forecasting System. --Taken from Teigan and Womack 1979.

The choice of structural equations was based on R^2 values, Durbin-Watson tests, their predictive ability in and out of the simultaneous solution method, and their effect on impact multipliers.

Retail supply and demand equations are of special interest to this research. "Retail demand equations are in price dependent form. The equations are homogeneous to degree zero in all prices and income and contains prices of both substitutes and complements" (Teigen and Womack 1979, p. 4). Retail supply equations reflect the production process that converts live animals in carcass weight of meat as a function of the number of animals slaughtered, retail price and the wage rate of the processing industry.

The combined system of structural models is solved for the implied reduced-form system. A Gauss-Seidel procedure is used to obtain the combined model solutions and impact multipliers. This solution method is part of the larger GASSP solution method (General Analytical Simulation Solution Program) (Kite n.d.). The solution for the system of equations takes place in 4 steps which are briefly described below:

1. Initial values for the independent variables are chosen for the entire system.
2. Dependent variables are estimated.
3. Estimates are compared to initial values. If they are significantly different, continue to the next step. If the estimates are not significantly different, the solution is complete.

4. Move estimates into the position of initial variables.

5. Return to step 2 and continue the iterations.

The advantage of this model is that it is easy to employ. The disadvantage is that solution convergence is not guaranteed. However, practical experience has shown the system to achieve convergence in an overwhelming majority of cases (Kite n.d.).

The C.C.F.S. serves to provide the information (economic indicators) necessary to compute the change in consumer welfare. Both the solution values (output) of the C.C.F.S. and the structural relationships within each commodity model are used to determine impact on consumers. The items needed to calculate the change in welfare are:

a. population

b. personal disposable income

c. slope coefficient on demand for each good

d. income elasticity of demand for each good

e. price of each good

f. quantity of each good.

Since the C.C.F.S. is based in Washington, D.C., the services of Reuben Weisz, USDA economist, were employed to conduct baseline and impact computer runs. He provided a printout of all structural equations, and the output for baseline and impact runs over a six year period (1980-85).

Population and disposable income were predetermined input into the C.C.F.S. The slope coefficients on demand were determined

directly from the structural relationships within each commodity model. Teigen and Womack (1979) presented the income elasticities of demand inherent in the C.C.F.S. in "An Econometric Model of the Livestock and Feed Sector."

Prices and quantities are collected as output from C.C.F.S. Prices were converted from indices to actual using base year 1967 (Bureau of Labor Statistics [BLS] 1967; USDA 1973, 1974). All prices are in terms of dollars per pound, with the exception of ice cream and egg prices. These are in terms of dollars per gallon and dollars per dozen, respectively. Quantities are in terms of total pounds, gallons and dozens.

The economic indicators for the dairy component of the C.C.F.S. required special adjustment in order to achieve a form suitable for calculation of welfare measures. Appendix A describes these adjustments in detail.

RESULTS AND ANALYSIS

Results

Alternate measures of consumer impacts due to the three percent reduction in corn yields projected to occur if insecticides for corn were banned are estimated for eleven commodities over a six year period. Table 2 summarizes the total loss in Marshallian surplus experienced by the nation's consumers over the six year period. Results are recorded by year and by commodity.

Losses according to commodity range from seven million dollars loss on ice cream to a loss of approximately 29 billion on beef. Losses in the first year amount to 500 million dollars and increase to a level of 16 billion dollars in the last year recorded. Total losses, over all commodities, for a six year period are estimated to be approximately 50 billion dollars.

When income effects are considered, estimates of the change in Marshallian surplus are modified to obtain compensating and equivalent variations. The Paasche and Laspeyres indices bound the range of values compensating variation, equivalent variation and the change in Marshallian surplus can assume. Table 3 presents estimates for all five measures by year. In addition, the change the Marshallian surplus as a percentage of disposable income and the deviation of Paasche and Laspeyres indices from Marshallian surplus are listed.

Table 2. Total losses in Marshallian surplus due to decreased corn yields, by year and commodity

Year / Commodity	1980	1981	1982	1983	1984	1985	Total by Commodity
	Billions of dollars						
Pork	.2577	.5810	1.4250	2.5036	2.7346	2.6700	10.1719
Beef	.0401	.1052	1.8146	6.6052	9.9773	10.2400	28.7824
Veal	.0020	.0092	.0987	.2856	.2482	.0617	.7054
Chicken	.1057	.2328	.5831	1.2034	1.5623	1.6467	5.3340
Turkey	(+)[a] .0002	.0158	.1539	.3434	.4560	.4724	1.4413
Eggs	.0651	.1453	.3315	.6625	.8685	.9602	3.0331
Ice Cream	.0013	.0013	.0013	.0012	.0011	.0011	.0073
Evap. Milk	.0013	.0028	.0024	.0018	.0015	.0013	.0111
Fluid Milk	.0282	.0563	.0534	.0512	.0236	.0234	.2361
Cheese	.0147	.0293	.0255	.0200	.0143	.0122	.1160
Butter	.0034	.0076	.0064	.0046	.0042	.0035	.0297
Totals	.5193	1.1866	4.4958	11.6825	15.8916	16.0925	49.8683

a. (+) indicates gain in welfare in 1980 only.

Table 3. Alternative estimates of total losses by year

Year	Population	Total Disposable Income	Paasche Index	Equivalent Variation	Marshallian Surplus	Compensating Variation	Laspeyres Index	Percent Deviation of Paasche and Laspeyres Indices from Marshallian Surplus	Marshallian Surplus as a Percentage of Disposable Income
	Millions	----------Billions of Dollars----------						----Percent----	
1980	221.9	1725	.5177	.5191	.5192	.5193	.5207	.3	.03
1981	223	1875	1.1804	1.1861	1.1865	1.1868	1.1925	.5	.06
1982	225	2033	4.4677	4.4909	4.4958	4.5007	4.5240	.6	.22
1983	226.7	2205	11.5331	11.6505	11.6824	11.7143	11.8317	1.3	.53
1984	228.4	2388	15.5895	15.8357	15.8917	15.9477	16.1940	1.9	.67
1985	230.1	2592	15.7438	16.0378	16.0915	15.1452	16.4391	2.2	.62
Total	1355.1	12818	49.0322	49.7201	49.8671	50.0140	50.7020	1.7	.39

Estimates of the total loss in consumer welfare, over a six year period range from 49 billion dollars to almost 51 billion dollars. The estimate of total change in Marshallian surplus is .39 percent of total disposable income. Paasche and Laspeyres indices differ from the change in Marshallian surplus by 1.7 percent.

Table 4 lists all items included in Table 3, but in terms of commodities. An average of yearly disposable income is used to calculate Marshallian surplus as a percentage of disposable income. Estimates of total losses, deviation of Paasche and Laspeyres indices from Marshallian surplus, and Marshallian surplus as a percentage of disposable income by commodity differ from estimates by year by rounding errors only.

Estimates of total losses (Table 3 and Table 4) are converted to per capita results presented in Table 5 and Table 6 using population provided as an exogenous variable into the C.C.F.S. Table 5 records per capita results by year. Estimates of loss range from 215 to 222 dollars per person over the six year period. Estimates of Marshallian surplus as a percentage of disposable income and the deviation of Paasche and Laspeyres from Marshallian surplus remain constant at .39 and 1.7 percent, respectively.

Table 6 is a transformation of Table 3 from total to per capita results by commodity. Averages of yearly population and disposable income were used to calculate results by commodity. Per capita totals by year (Table 5) and by commodity (Table 6) differ due to rounding errors.

Table 4. Alternate estimates of total losses by commodity, 1980-1985

Commodity	Average Population	Average Annual Total Disposable Income	Paasche Index	Equivalent Variation	Marshallian Surplus	Compensating Variation	Laspeyres Index	Percent Deviation of Paasche and Laspeyres Indices from Marshallian Surplus	Marshallian Surplus as a Percentage of Disposable Income
	Millions	-----------------Billions of dollars-----------------------						-----Percent------	
Pork	226	2136	10.0891	10.1202	10.1716	10.2229	10.2540	.8	.079
Beef	226	2136	28.3139	28.5929	28.7819	28.9709	29.2499	1.6	.223
Veal	226	2136	.5650	.7030	.7054	.7077	.8458	19.9	.006
Chicken	226	2136	5.2039	5.2849	5.3339	5.3830	5.4639	2.4	.042
Turkey	226	2136	1.4303	1.4409	1.4413	1.4417	1.4523	.8	.011
Eggs	226	2136	3.0284	3.0312	3.0330	3.0349	3.0377	.1	.023
Ice Cream[a]	226	2136	.0072	.0073	.0073	.0073	.0074	1.4	.000
Evap.Milk[a]	226	2136	.0109	.0110	.0110	.0110	.0111	.9	.000
Fluid Milk[a]	226	2136	.2341	.2361	.2361	.2361	.2380	.8	.002
Cheese[a]	226	2136	.1150	.1160	.1160	.1160	.1170	.9	.001
Butter[a]	226	2136	.0293	.0296	.0296	.0296	.0298	.7	.000
Total	1356	12818	49.0271	49.5731	49.8671	50.1611	50.7069	1.7	.39

a. Estimates for CV, EV and MS are equal because income elasticities for all dairy products are zero (Teigan 1979).

Table 5. Alternative estimates of per capita losses by year

Year	Population	Per Capita Disposable Income	Paasche Index	Equivalent Variation	Marshallian Surplus	Compensating Variation	Laspeyres Index	Percent Deviation of Paasche and Laspeyres Indices from Marshallian Surplus	Marshallian Surplus as a Percentage of Disposable Income
	Millions	Thousands	---------------	---------------	Dollars	---------------	---------------	-----Percent-----	
1980	221.9	7.8	2.33	2.34	2.34	2.34	2.35	.4	.03
1981	223	8.4	5.29	5.31	5.32	5.33	5.35	.5	.06
1982	225	9.0	19.86	19.96	19.98	20.00	20.11	.6	.22
1983	226.7	9.7	50.87	51.39	51.53	51.67	52.19	1.3	.53
1984	228.4	10.5	68.26	69.33	69.58	69.83	70.90	1.9	.67
1985	230.1	11.3	68.42	69.70	69.93	70.16	71.44	2.2	.62
Total	1355.1	56.7	215.03	218.03	218.68	219.33	222.34	1.7	.39

Table 6. Alternate estimates of per capita losses by commodity, 1980-1985

Commodity	Average Population	Average Annual Per Capita Disposable Income	Paasche Index	Equivalent Variation	Marshallian Surplus	Compensating Variation	Laspeyres Index	Percent Deviation of Paasche and Laspeyres Indices from Marshallian Surplus	Marshallian Surplus as a Percentage of Disposable Income
	Millions	Thousands	-----------	-----------	Dollars	-----------	-----------	-------Percent	------
Pork	226	9.45	44.64	44.78	45.00	45.23	45.37	.8	.079
Beef	226	9.45	125.28	126.52	127.35	128.19	129.42	1.6	.223
Veal	226	9.45	2.49	3.11	3.12	3.13	3.74	19.9	.006
Chicken	226	9.45	23.05	23.38	23.60	23.82	24.15	2.3	.042
Turkey[a]	226	9.45	6.33	6.38	6.38	6.38	6.43	.8	.011
Eggs	226	9.45	13.40	13.41	13.42	13.43	13.44	.1	.023
Ice Cream[b]	226	9.45	.03	.03	.03	.03	.03	.0	.000
Evap.Milk[b]	226	9.45	.05	.05	.05	.05	.05	.0	.000
Fluid Milk[b]	226	9.45	1.03	1.04	1.04	1.04	1.05	1.0	.002
Cheese[b]	226	9.45	.50	.51	.51	.51	.52	.0	.001
Butter[b]	226	9.45	.13	.13	.13	.13	.13	.0	.000
Total	1356	56.70	216.93	219.34	220.63	221.94	224.33	1.7	.39

a. Estimates of CV, EV and MS differ, but are not significant when rounded to the nearest cent.

b. Estimates of CV, EV and MS are equal because income elasticities for all dairy products are zero (Teigan 1979).

Analysis

The empirical test conducted demonstrates overwhelmingly that a decrease in corn yields would have a negative impact on consumers. But, the results suggest that in this multiproduct case, where a complete cessation of insecticide use on corn results in a three percent reduction in yields, the difference between alternative welfare measures is very small.

Estimates by Commodity and Over Time

Impacts on individual commodities took varied patterns. For example, the negative impacts attributable to consumption of beef increase exponentially, the impacts on veal increase then subside and welfare due to turkey consumption actually shows a one year gain before losses set in (Table 2). The welfare gain derived from turkey in the first year is the only one of its kind and is probably due to a short term substitution effect.

The distribution of losses between commodities is uneven (Table 6). Beef accounts for over 50 percent of welfare losses. Pork and beef combined make up approximately 78 percent of the negative impacts. Relative losses by commodity are illustrated in Figure 16.

In order to shed some light on the sequence and magnitude of welfare losses, production of each commodity over time was examined. Figure 17 plots the production of each commodity as a percent of 1980 output (the year of initial impact). Point A represents the initial equilibrium. If one assumes initial stocks of corn are stable at the

Figure 16. Relative per capita welfare losses by commodity.

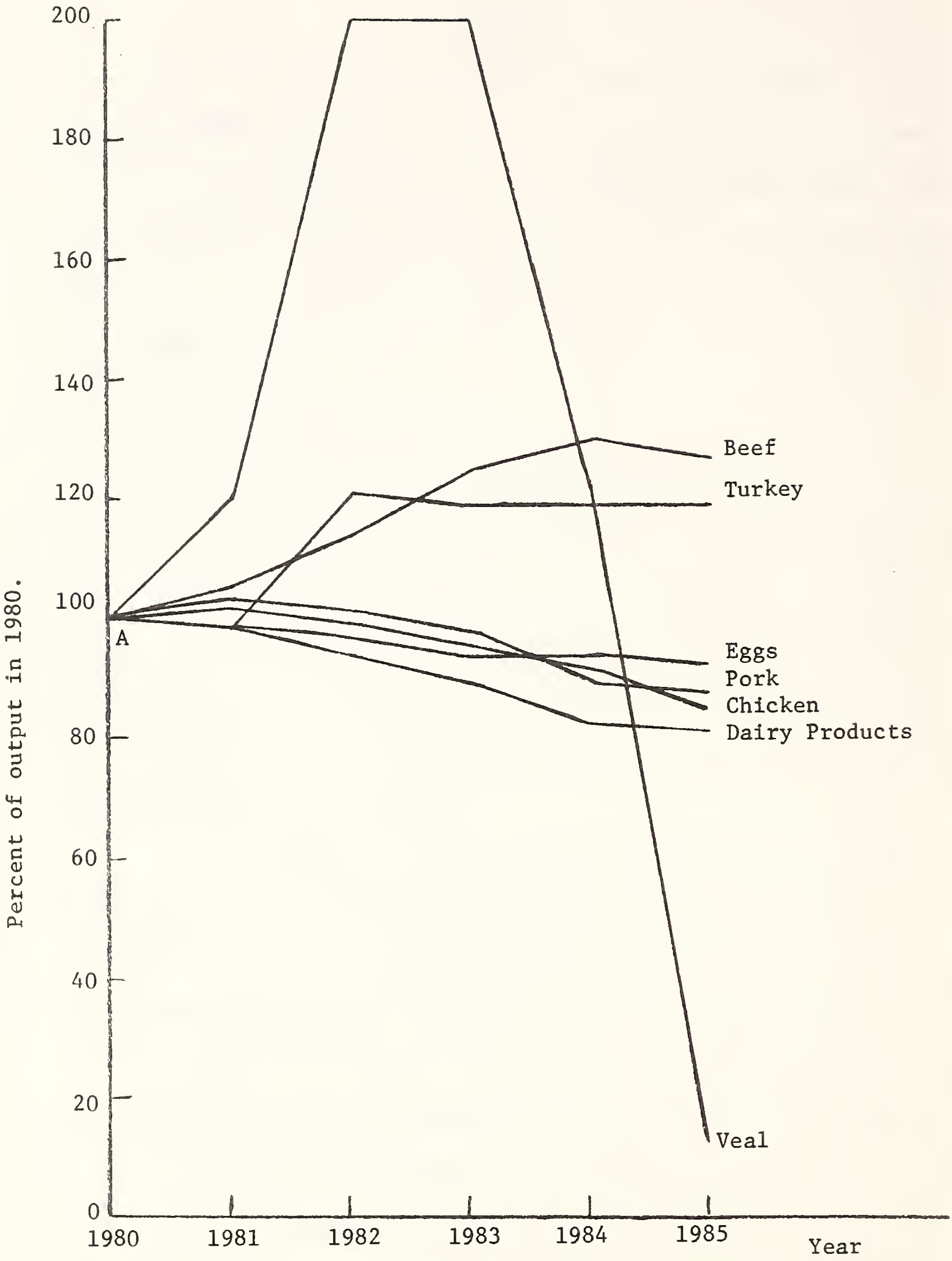


Figure 17. Livestock production as a percent of 1980 output.

point of impact, one can imagine abrupt depletion evoking complications in the entire sector.

In general, reduction in corn yields caused an increase in the price of every commodity. The increase in production of beef and turkey, coupled with an increase in price, indicates an increase in the demand for these goods. Reduction in production of eggs, pork, chicken and dairy products reflects the indirect decrease in supply of these goods via corn yields. The direction of demand in these cases is uncertain. Veal shows the most extreme pattern of production. It appears that as a result of price increase in substitutes for veal, the demand and production of veal increased in the short run. Then, as its own price increased, substitution shifted back toward beef and turkey, causing virtual elimination of veal production.

By 1985, production of livestock commodities, with the exception of veal, stabilize. The new equilibrium level appears to have been reached. A significant change in veal production may occur after 1985, but because it is a relatively unimportant livestock product, its effect on welfare measures would be small.

This pattern of production, along with other economic indicators, translates into welfare losses of between 217 and 224 dollars per person over a 6 year period (Table 6). When welfare estimates are looked at over time, per capita impacts increase exponentially for four years, increase at a decreasing rate the fifth year and stabilize the sixth year (Figure 18).

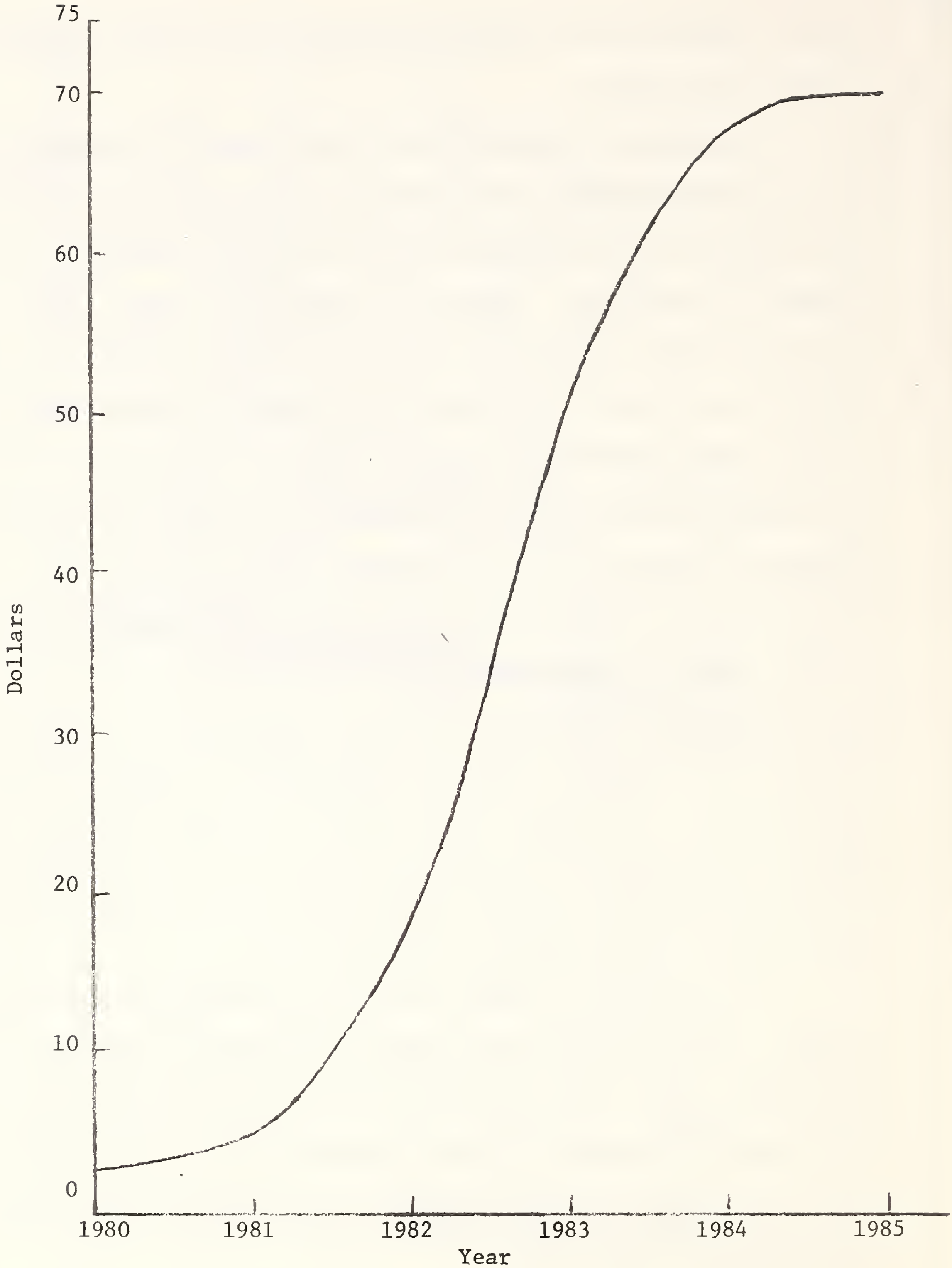


Figure 18. Per capita losses over time.

Loss in Marshallian Surplus Relative to Disposable Income

This research indicates that welfare losses due to lower corn yields would be small in relation to disposable income.

Losses in Marshallian surplus attributable to beef constitute .079 percent of average yearly disposable income (Table 6). Losses on all other commodities are less than one quarter of one percent of average yearly disposable income.

Loss in Marshallian surplus the first year constitutes three hundredths of one percent of yearly disposable income (Table 5). This percentage increases to about .7 percent in year five dropping to .6 percent in year six. In total, losses in Marshallian surplus over all commodities for six years are .4 percent of disposable income for six years.

Income Effects

The most important feature of these results is that these results exhibit a very small discrepancy between welfare measurements of a rather large policy change. In this application, Paasche and Laspeyres indices by themselves place fairly tight restrictions on the range of values a change in welfare can assume.

Looked at by commodity, Paasche and Laspeyres indices differ from Marshallian surplus by about one percent in most cases. The estimates for veal exhibit the widest range of values in relative terms. Paasche and Laspeyres indices for veal are 19 percent less than and greater than Marshallian surplus, respectively. However, in

absolute terms the difference is only 62 cents. The relatively wide range of welfare estimates for veal is due to the large changes in veal production exhibited by Figure 17.

Deviation of Paasche and Laspeyres indices from Marshallian surplus increase over time from .4 percent in the first year to 2.2 percent in the last. In total, the deviation of index numbers is 1.7 percent from Marshallian surplus.

Gordon and Knetsch (1979) have documented the difference between CV and EV as being between a factor of 3 and 20. The results presented here indicate otherwise. Estimates for CV and EV are within 1% of each other in every case. One explanation for the small discrepancy is that in this study, welfare changes are inferred from simulated behavior, not gathered as verbal quantification of willingness to pay and/or require compensation. People may tend to bias verbal responses in a manner most effective for their purposes.

Also, the circumstances surrounding the studies examined by Gordon and Knetsch are different from the empirical work presented here. Gordon and Knetsch address cases where consumers are questioned as to their willingness to pay to continue an activity and the compensation required to <u>completely</u> <u>forego</u> an activity. This research considers a change in price only. It is reasonable to believe that the extreme cases sighted by Gordon and Knetsch would yield more extreme values for compensating and equivalent variation.

In contrast, Willig (1976) maintains that in a majority of cases, compensating and equivalent variation will be within two

percent of Marshallian surplus. The results of this research are in line with his estimates. The conditions set forth by Willig in order to have CV and EV within 2% of Marshallian surplus are:

1. The change in Marshallian surplus must be less than 5% of the consumer's income.
2. Income elasticities of demand must be between ± 1.

The first condition is met in every case. Total losses are .39 percent of disposable income. All income elasticities used in the C.C.F.S. are between ± 1, with the exception of beef and chicken which are 1.08 and 1.7 percent respectively (Teigan and Womack 1979). However, even with this slight violation of Willig's conditions, all results for compensating and equivalent variation are within one percent Marshallian surplus.

The adjustments introduced through income effects are trivial. In every case, estimates for compensating and equivalent variation are within one percent of estimates with no income effects. In total, per capita income effects are approximately 65 cents. These results imply that consideration of income effects may not be essential to a reasonably accurate set of estimates for a change in welfare. In the words of J. R. Hicks, "There is no theoretical object to this sort of adjustment, but it is a fiddling business, fortunately not likely to be of much importance" (Hicks 1941, p. 109).

Application Techniques

One of the most important conclusions drawn from this study is that practical application of Hicksian measures is relatively simple. Paasche and Laspeyres indices can be calculated from simple observation of price and quantity. A change in welfare with no income effect may be calculated from the same data, given demand is assumed to be linear. Estimation of CV and EV require knowledge on income and income elasticity in addition to prices and quantities. Some believe welfare economists cannot adequately define a change in welfare, much less measure it. An exact definition of a change in welfare escapes even the finest philosophers. But theories of welfare, in their present state, do have appropriate, useable techniques of measurement.

Traditional Mistakes

In this section traditional mistakes made by analysts in evaluating consumer welfare changes are examined.

Misinterpretation of Marshallian Concepts

One major measurement problem lies in the misinterpretation of Marshallian concepts by economists. Consider Figure 19. The consumer begins at point A paying P_o for each of Q_o units of a good. If supply decreases from S^o to S^1 the consumer is at point B, paying P_1 for each of Q_1 units. If income effects are zero, the income equivalent of his loss in welfare is represented by P_oABP_1. This area happens to be equal to $P_oDA - P_1DB$.

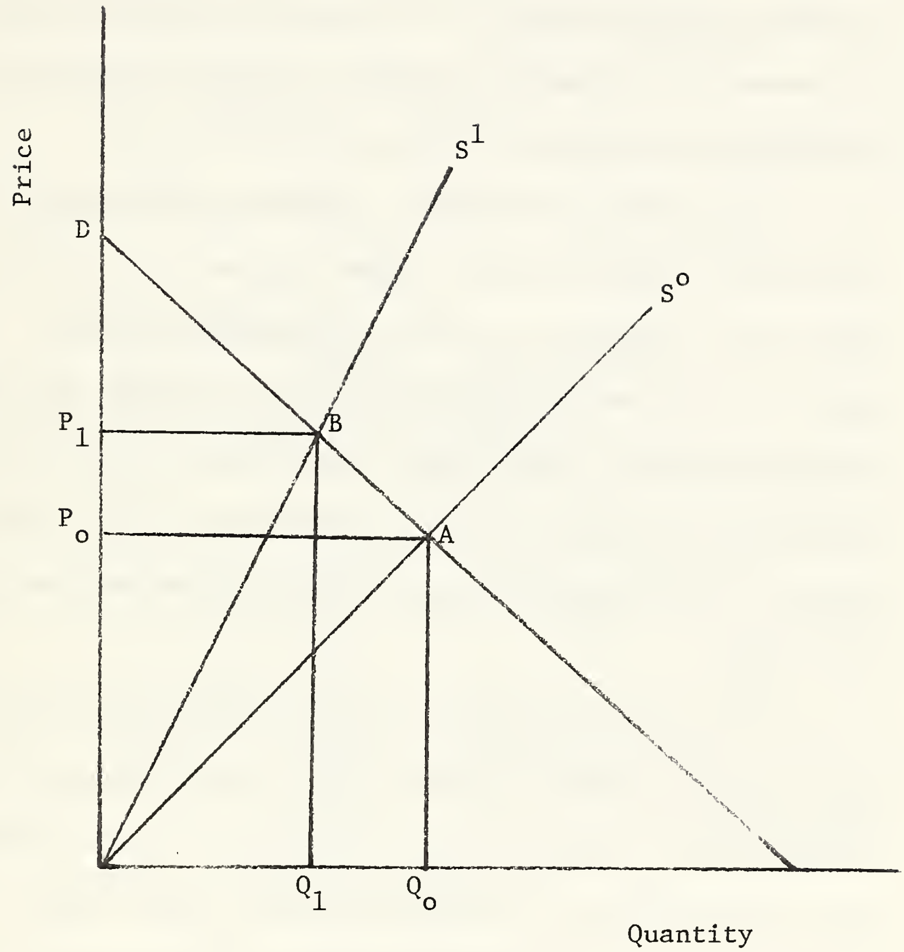


Figure 19. Measurement of a change in Marshallian surplus with demand fixed.

Problems arise when demand is allowed to fluctuate (Figure 20). The same conditions apply as in Figure 19 but in this case, due to the decrease in supply and reverberations within the economy, the consumers demand decreases from D^o to D^1 and he ends up at point C. The correct measure of a change in welfare is P_oACP_1 as detailed in Figure 10 and verified by Hicksian (1942) equation (23).

The problem is that some economists misinterpret the correlation between total area under demand and above price and a change in welfare that exists in the case where demand is stable. If one confuses the relationship between totals and a change and extends this misinterpretation to cases where demand shifts, the change in welfare illustrated by Figure 20 may be evaluated as $P_oAD^o - P_1CD^1 = P_oAD^oD^1P_1$. Obviously, this result is grossly deviant from the true income equivalent P_oACP_1.

The key to exclusion of area D^1CAD^o is that D^o and D^1 are <u>ceteris paribus</u> demand curves. That is, they represent behavior by consumers when only the price of the good in question changes. A different demand curve is relevant when many prices change. In this case points C and A are two observed points on that demand curve. Given demand when many prices change is linear, segment P_oACP_1 becomes part of the demand relevant to welfare measurement.

If comparison of total is used to evaluate a three percent reduction in corn yields, the result is a set of numbers as shown in column 2 of Table 7. The fact that these results lie outside Paasche and Laspeyres indices demonstrates that comparison of totals below

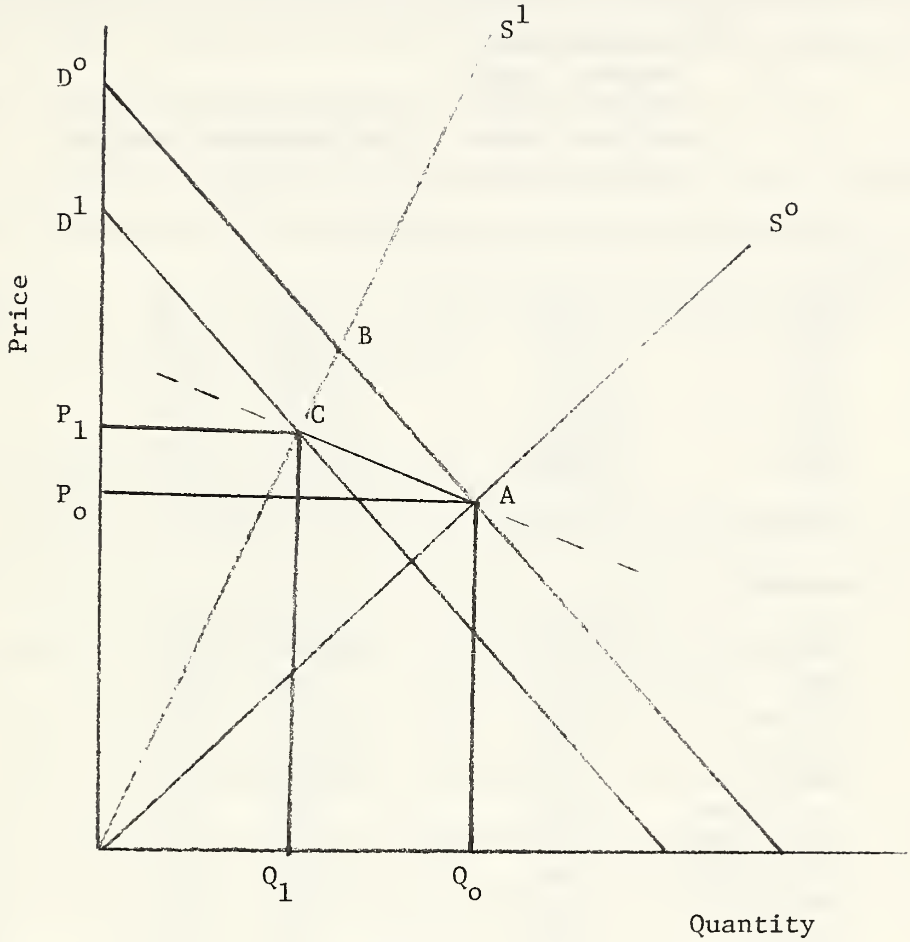


Figure 20. Measurement of a change in Marshallian surplus when demand shifts.

Table 7. Per capita losses derived from Paasche and Laspeyres indices, change in expenditures and comparison of totals below demand and above price

	Difference between totals under demand and above price	Range between Paasche and Laspeyres indices	Change in expenditures
	--------Dollars--------		
Year			
1980	1.42	2.33 - 2.35	(+)[a] .14
1981	2.02	5.29 - 5.35	.88
1982	5.15	19.86 - 20.11	12.07
1983	13.53	50.87 - 52.19	36.47
1984	22.85	68.26 - 70.90	47.64
1985	27.08	68.42 - 71.44	42.11
Total	72.05	215.03 -222.34	139.03
Commodity			
Pork	12.45	44.64 - 45.37	34.00
Beef	40.29	125.28 -129.42	96.26
Veal	1.37	2.49 - 3.71	(+)[a] 8.29
Chicken	16.85	23.05 - 24.15	16.90
Turkey	.06	6.33 - 6.43	5.88
Eggs	.31	13.40 - 13.44	12.97
Ice Cream	.03	.03 - .03	(+)[a] 1.20
Evap. Milk	.04	.05 - .05	(+)[a] .29
Fluid Milk	.86	1.03 - 1.05	(+)[a] 12.29
Cheese	.39	.50 - .52	(+)[a] 2.47
Butter	.10	.13 - .13	(+)[a] .49
Total	72.75	216.93 -224.33	140.27

a. (+) indicates a decrease in expenditures.

demand and above price, when demand shifts, is an incorrect form of welfare measurement. Using these incorrect estimates, total per capita losses over 6 years are 1/3 of the magnitude of that estimated through Hicksian (1942) techniques ($72 as compared to $220).

In fact, the whole concept of comparing totals under demand is invalid. The intercept of a particular demand curve is never observed. Our knowledge is limited to the neighborhood of demand that encompasses current prices and quantities.

Change in Expenditures as an Index of Welfare

As noted in Chapter 1, many economists use change in expenditures as an index of a change in welfare. Again, this procedure cannot be justified. An increase or decrease in expenditures says nothing about the direction of a welfare change. Both can and do occur simultaneously regardless of whether welfare increases or decreases. Measuring the change in expenditures due to a policy change follows the redistribution of money between commodities, not the welfare that stems from that distribution.

Table 7, column 4, documents the per capita change in expenditures due to decreased corn yields. These numbers have no consistent correlation with the correct measure of welfare change. Expenditures on some commodities increase while expenditures on others decrease, as one would expect. Per capita expenditures would increase $140 for a 6 year period.

In the present study, both misinterpretation of surplus concepts and the use of an expenditure index grossly underestimate the loss in consumer welfare due to a decrease in corn yields.

Reservations

Assumptions

The theory presented is valid within the boundaries of assumptions made. A perfectly competitive market is assumed. This assumption appears legitimate, especially in the agriculture sector. However, there may be some facets of the commodity group studied that approach being monopolistic. If so, as discussed in Chapter 2, measures of compensating and equivalent surplus may be more appropriate than compensating and equivalent variation.

Modeling

Empirical results are conditional upon the model used to describe behavior, in this case the C.C.F.S. Computer models are simplifications of the real world and therein lies their limits. For example, in the C.C.F.S., retail demand equations are linear. This structural form is convenient for interpretation of welfare changes, but one would not expect actual behavior to follow such a simplistic pattern.

All structural equations are bound to have defects. Whether these defects are large enough to warrant concern is the question. There may be some variables that describe livestock production, consumer response, etc., that have been inadvertently omitted or

misstated. Inclusion of perfect describers would modify our estimates of a change in welfare, to what degree is uncertain. It is unlikely that model refinement would change estimates by a significant order of magnitude.

General Equilibrium

This research is fairly comprehensive in that it extends analysis beyond a particular commodity to an entire food group (livestock products). One would expect the largest fraction of economic impulses stemming from decreasing corn yields to be felt in the livestock sector. However, one cannot ignore the fact that other sectors of the economy would respond, modifying the amount of actual change estimated.

The time period analyzed is also somewhat arbitrary. There is a possibility that a significant economic impact of lowered corn yields has been overlooked by limiting the analysis to six years. However, impacts stabilize in year six and are believed to continue at that level.

Focus on Consumers

A comprehensive analysis of policy impacts would entail consideration of many groups, e.g., producers, marketers, consumers, etc. The focus of this research has been on consumers only.

As a result, even if the estimates of net losses to consumers are correct, an automatic recommendation against the policy is not justified. All concerned relevant groups must be considered to make an ultimate assessment of total impact.

Equity

The empirical estimations of this study are based on aggregate retail demand. There is no measurement of how these costs and benefits are distributed among consumers. In order to delineate the arrangement of losses, individual responses must be estimated, then summed to obtain aggregate results. Because this study rests on the foundation of an aggregate model, no conclusions can be drawn as to whether or not the distribution of losses is equitable.

APPENDIX A

DAIRY MODEL ADJUSTMENTS

The dairy component of the cross commodity forecasting system posed some special problems. The dairy model includes several products derived from a homogeneous input (milk). The dairy model is made up of ice cream, evaporated milk, fluid milk, cheese and butter.

Unlike the other commodities, the price of each dairy product is implicitly, rather than explicitly a function of the quantity of milk produced. Generally, the dairy product equations are of the form, retail price = f(farm price) = f(quantity of milk). In order to achieve an equational form suitable for computation of welfare measures, the latter equations were incorporated into the former. An example of the composite dairy functions follows:

Retail price index of cheese $Y(80) = .105418\ Y(141) + .144625\ Y(68)$

Farm price of milk $Y(68) = -\ .022904\ Y(67) + 2.9685\ Y(81)$

Weighted dairy retail price index $Y(81) = .299655\ Y(79) + .1512261\ Y(80) + .0531791\ Y(75) + .0004382\ Y(78) + .0936883\ Y(77) + .5573033\ Y(76)$.

Therefore:

$$Y(80) = .105418\ Y(141) + .144625\ (-\ .022904\ Y(67) + 2.9685\ (.299655\ Y(79) + .1512261\ Y(80) + .0531791\ Y(75) + .0004382\ Y(78) + .0936883\ Y(77) + .5573033\ Y(76)))$$

$$= .1127375\ Y(141) + .1375822\ Y(79) + .02441636\ Y(75) + .00020119\ Y(78) + .04301554\ Y(77) + .25587724\ Y(76) - .00354254\ Y(67).$$

Now that the price of each dairy product is expressed as a function of total milk production, another problem arises. The total amount of milk produced appears in each dairy equation. Obviously, the total amount of milk produced is not used for any one dairy product. The total amount is distributed among dairy components. In order to determine what percentage of total milk output should be attributed to each component, the ESCS summary report on dairy products was consulted. It was found that the quantity of a dairy component could be consistently expressed as a percentage total of milk production. (USDA 1978b). Table A-1 shows that over an 18 year period (1960-1977), the average percentage of total milk used for manufactured dairy products was 53.32%. Over this time period, the actual percentage never deviates more than 3% from the average. An average of 46.68% remained as whole fluid milk.

Table A-2 shows the distribution of whole milk for manufactured dairy products between cheese, evaporated milk, frozen products and other dairy products. Although 10 years of data are available, only the years 1973-77 were used to calculate an average percentage. Due to the trends over time, it appears that the last 5 years would serve as a more accurate predictor of the distribution of milk between dairy products. For example, the percentage of milk for manufacturing frozen dairy products and "other" dairy products remained relatively constant over a 10 year period. The percentage used for butter and

Table A-1. Milk marketings and utilization for manufactured dairy products, United States, 1960-77 -- Taken from USDA 1978b, p. 1.

Year	Milk Marketed: Total	Milk Marketed: Used for Dairy Products	Year	Milk Marketed: Total	Milk Marketed: Used For Dairy Products
	Million Pounds	Percent		Million Pounds	Percent
1960	113,756	52.5	1969	111,793	52.1
1961	117,007	54.3	1970	112,999	53.1
1962	118,348	54.2	1971	114,814	53.7
1963	117,982	53.1	1972	116,487	53.5
1964	120,531	53.5	1973	112,141	52.3
1965	118,206	52.3	1974	112,385	54.6
1966	114,440	50.6	1975	112,262	53.9
1967	113,567	52.6	1976	117,303	55.1
1968	112,563	52.6	1977	120,127	55.7

Table A-2. Net whole milk equivalents used in manufactured dairy products: total and percentage distribution by major products, United States, 1968-77 -- Taken from USDA 1978b, p. 67.

Year	Total	Percentage Distribution					
		Butter	Cheese	Evaporated Milk	Frozen Products	Other Milk Products	Total
	Million Pounds	---Percent---					
1968	59,230	42.1	29.3	6.6	18.5	3.5	100.0
1969	58,228	40.6	30.3	6.6	18.9	3.6	100.0
1970	60,013	39.9	32.6	5.4	18.4	3.7	100.0
1971	61,614	38.8	34.0	5.3	17.8	4.1	100.0
1972	62,319	36.5	36.7	5.0	17.6	4.2	100.0
1973	58,678	31.7	40.2	5.0	18.9	4.2	100.0
1974	61,327	31.5	41.9	4.6	18.2	3.8	100.0
1975	60,524	32.8	39.5	4.5	19.7	3.5	100.0
1976	64,673	30.0	44.5	3.9	18.0	3.6	100.0
1977	66,863	32.7	43.2	3.5	17.3	3.3	100.0

evaporated and condensed milk have continually decreased while the percentage used for cheese has increased.

Table A-3 shows the average percentage of the milk for manufactured products accounted for by each category of dairy product. From these data, the percentage of all whole milk accounted for by each dairy product is estimated. For example, the percentage of milk used in manufacturing accounted for by cheese multiplied by the percentage of total milk accounted for by that used in manufacturing equals the percentage of total milk accounted for by cheese.

At this point the slope coefficient on quantity of total milk used in each dairy product-demand equation must be adjusted. Using cheese as an example, the original demand equation is

$$P = a - .00354254\ (Y67)$$

where

P = price of cheese

a = intercept

(Y67) = total milk production.

Since cheese is 22.3 percent of total milk production, the equation is adjusted as follows:

$$P = a - \frac{.00354254}{.223} \quad .223\ (Y67)$$

$$P = a - (.01588583)\ (.223(Y67))$$

where

.223 (Y67) is interpreted as the quantity of milk used for cheese.

Table A-3. Average percentage distribution of milk in manufacturing and total milk between major dairy products[a]

	Percentage Distribution						
	Butter	Cheese	Evaporated Milk	Frozen Products	Fluid Milk	Other	Total
Milk in manufacturing	31.74	41.86	4.3	18.42	0	3.68	100.0
Total milk	16.9	22.3	2.3	9.8	46.68	2.02	100.0

a. Derived from Tables A-1 and A-2.

To arrive at the actual amount of cheese, conversion factors from milk to each dairy product were used (Table A-4). For example, the quantity of milk used for cheese is multiplied by the amount of cheese produced per pound of milk to obtain:

$$P = a - .01588583\ (.223)\ (Y67)$$

$$P = a - \frac{.01588583}{.1}\ (.1)\ (.223)\ (Y67)$$

$$P = a - .1588583\ (.0223Y67)$$

where

.0223 (Y67) equals the quantity of cheese.

Even though the demand equations have remained essentially unchanged, these adjustments may make a significant difference in the calculations of welfare measures since both the slope coefficient and quantity change.

Table A-4. Major dairy products, their milk equivalents and conversion factors -- Taken from USDA 1978a, p. viii.

Dairy Product	Milk Equivalent	Conversion Factor
1 gal. ice cream	15 lbs.	.0667
1 lb. evaporated milk	2.14 lbs.	.467
1 lb. cheese	10 lbs.	.1
1 lb. butter	21 lbs.	.0476

REFERENCES

Boutwell, Wayne, C. Edwards, R. Haidacher, H. Hogg, W. E. Kost, J. B. Penn, J. M. Roop and L. Quance. "Comprehensive Forecasting and Projection Models in the Economic Research Service," Agricultural Economics Research, 28:41-45, 1976.

Bureau of Labor Statistics, Handbook of Labor Statistics, U.S. Department of Labor, Washington, D.C., 1967.

Burns, Michael E. "A Note on the Concept and Measurement of Consumers' Surplus," American Economic Review, 63:335-44, 1973.

Currie, John Martin, John A. Murphy and Andrew Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis," The Economic Journal, 81:741-799, 1971.

Dupuit, Jules, "On the Measurement of the Utility of Public Works," International Economics Papers, 2:83-110, 1952.

Gordon, Irene and J. L. Knetsch. "Consumer's Surplus Measures and the Evaluation of Resources," Land Economics, 55:1-10, 1979.

Hause, John C. "The Theory of Welfare Cost Measurement," Journal of Political Economy, 83:1145-81, 1975.

Henderson, A. "Consumer's Surplus and the Compensating Variation," Review of Economic Studies, 8:117-121, 1941.

Hicks, John R. Value and Capital, Oxford University Press, 1939.

________. "The Rehabilitation of Consumers' Surplus," Review of Economic Studies, 8:108-116, No. 2, 1941.

________. "Consumer's Surplus and Index Numbers," Review of Economic Studies, 9:126-137, No. 2, 1942.

Kite, Rodney. "General Analytical Simulation Solution Program Manual," Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Washington, D.C., unpublished paper, no date.

Marshall, Alfred. Principles of Economics, Macmillan and Co., London, 1966, (First edition, 1898.)

Martin, William E., Craig J. Tinney and Russell L. Gum. "A Welfare Economics Analysis of the Potential Competition between Hunting and Ranching," Western Journal of Agricultural Economics, 3:88, December 1978.

Mishan, E. J. "Realism and Relevance in Consumer's Surplus," Review of Economics Studies, 15:27-33, 1947-48.

Patinkin, Don. "Demand Curves and Consumer's Surplus," in Carl Christ et al., Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld, 1963.

Pfouts, R. W. "Theory of Consumers' Surplus," Southern Economic Journal, 19:324-326, 1953.

Pimental, David and Christine Shoemaker. "An Economic and Land Use Model for Reducing Insecticides on Cotton and Corn," Environmental Entomology, 3:10-19, 1974.

Randall, Alan. "Economic Surplus and Benefit Cost Analysis," unpublished paper, Department of Agricultural Economics, University of Kentucky, pp. 5-6, 1978.

Teigen, Lloyd D. "The Income Redistribution Effects of the Meat Import Act," Economics, Statistics and Cooperatives Service, Commodity Economics Division, U.S. Department of Agriculture, Washington, D.C., working paper, 1977.

________ and Abner W. Womack. "An Econometric Model of the Livestock and Feed Sector," Economics, Statistics and Cooperatives Service, Commodity Economics Division, U.S. Department of Agriculture, Washington, D.C., speech, 1979

U.S. Department of Agriculture. "Livestock and Meat Statistics," Economic Research Service/Statistical Reporting Service, Agricultural Marketing Service, Washington, D.C. 20250, Statistical Bulletin 522, 1973.

U.S. Department of Agriculture. "Poultry and Egg Statistics," Economic Research Service/Statistical Reporting Service, Agricultural Marketing Service, Washington, D.C. 20250, Statistical Bulletin 525, 1974.

U.S. Department of Agriculture. "Agriculture Statistics," Economic Research Service/Statistical Reporting Service, Agricultural Marketing Service, Washington, D.C. 20250, 1978a.

U.S. Department of Agriculture. "Dairy Products Annual Summary," Economics, Statistics and Cooperatives Service, Commodity Economics Division, Washington, D.C., 1978b.

U.S. Department of Agriculture. "Food Consumption Prices Expenditures," Economics, Statistics and Cooperatives Service, Commodity Economics Division, Washington, D.C., 1978c.

U.S. Department of Agriculture. "Nitrite in Bacon, A Summary Analysis of a Ban on the Use of Nitrite in Curing Bacon," Economics, Statistics and Cooperatives Service, ESCS-44, Washington, D.C., 1978d.

Willig, Robert D. "Consumers Surplus Without Apology," The American Economic Review, 66:589-97, 1976.